Pricing through Uncertainty: Quality Ambiguity, Market Dynamics, and the Viability of Pricing Practices

Xiaolu Wang

Submitted in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy
in the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2016

ABSTRACT

Pricing through Uncertainty: Quality Ambiguity, Market Dynamics, and the Viability of Pricing Practices

Xiaolu Wang

Pricing practices of firms are an important yet little studied aspect of the price phenomenon in sociology. This study asks the question: Why do different firms, even in the same market, tend to use different pricing practices—value-informed, competition-informed, or cost-informed pricing—to set prices? To answer this question, this study builds a dynamic flocking model of pricing to investigate the *inter-dynamics* among pricing practices and various market uncertainties. The model shows that each pricing practice is only viable under certain combinations of levels of different market uncertainties. Supporting evidence, theoretical innovations, and practical implications of the model are discussed. Contrary to common intuition, uncertainty, conceptualized as some *cognitive tolerance interval*, is akin to lubricant, making the otherwise rigid, brittle, and friction-fraught system more smooth, robust, and error-tolerant under certain circumstances. Therefore, uncertainties, and the inter-dynamics among them, should be treated as an endogenous and integral part of the social mechanism at issue, rather than some amorphous "other" external to it.

Table of Contents

List of Figures

Acknowledgements

This dissertation would not be possible in its present shape without my mentor Professor Michael E. Sobel at Columbia University. Although the topic of my dissertation does not directly intersect with his research interests, his belief in it and unconditional support have long been a necessary condition for its continuous evolvement and final completion. His scholarship characterized by rigor, honesty, accuracy, and self-criticality has always been a model for my research. His careful reading and insightful feedbacks were instrumental to the writing of each and every version and iteration of my dissertation. His generosity, sincerity, thoughtfulness towards people surrounding him made my years at Columbia full of warm memories.

The pioneering works of Professor Harrison C. White at Columbia University provided the direct inspiration for my dissertation project. In his intellectually involving classes, I was deeply stimulated by his unique genius of alchemizing multi-disciplinary perspectives into a unifying theoretical insight. I am especially thankful to him for his enthusiastic encouragement and recognition of my critical extension of his path-breaking theories.

I am extremely grateful to Professor Felix Elwert at University of Wisconsin-Madison, my intellectual guide and dearest friend during my three years in Madison. The great patience he exercised in perusing various versions of my dissertation and his incisive comments were of big help for me to keep improving my thesis. Most importantly, the generous support and encouragement he offered as a dependable friend were indispensable for me to go through the difficult times of my years in Madison and beyond.

I am also indebted to Professor James Montgomery at University of Wisconsin-Madison. His technical classes of modeling various social mechanisms, structures, and dynamics provided a systematic perspective for me to situate my own modeling approach within a broader field of mathematical models in social science. His feedback on an earlier version of my dissertation is also much appreciated.

I must thank Professor Josh Whitford and Professor Yinon Cohen at Columbia, and Professor Paolo Parigi at Stanford, who are all on my dissertation committee, for their invaluable support, help, and feedback in the various stages of the development of my thesis.

I am very thankful to Professor Randal Collins at University of Pennsylvania for his patient listening to my introduction to this dissertation project, careful reading of the thesis, and enthusiastic recognition.

I deeply appreciate Professor Mark Gould and other participants in the "Younger Sociologists Series" at Haverford College in spring 2014 for their encouraging and constructive comments on my presentation based on the dissertation.

I also thank the participants of the 106^{th} ASA Annual Meeting in Las Vegas in 2011, of the Humane Studies Fellowship Research Colloquium at George Mason University in 2009, and of the 5^{th} Inter-Ivy Sociology Symposium at Columbia University in 2009, for their helpful feedbacks on the earlier versions of my dissertation.

At last, I have to express my most sincere gratitude to Professor Yuan Shen at Tsinghua University and Professor Xueguang Zhou at Stanford University, as they were among the first who encouraged and helped me to pursue an academic career in sociology and showed interest and belief in my dissertation project.

For my parents, Wang Jinzhong and Chen Zhihong

Introduction

Price has been a core variable in economics. For neoclassical economics, the law of supply and demand is about determining the equilibrium price; for the Austrian economists, price is the capsule carrier of market information crucial to the functioning of markets either in or off equilibrium (Hayek, 1945; Kirzner, 1973). In contrast, price receives only limited and fragmented attention in the current literature of sociology (Uzzi and Lancaster, 2004; Zhao, 2008). “In many studies on markets coming out of economic sociology, prices are not mentioned at all” (Beckert, 2011, p. 3), and this has been recognized as a “profound shortcoming” (Beckert, 2011; Uzzi and Lancaster 2004), especially considering the significant position of the sociology of markets in economic sociology (Carruthers and Uzzi, 2000; Fligstein and Dauter, 2007; Fourcade, 2007). Sociologists’ reluctance to study prices may be traced back to Max Weber, who explicitly states that price formation (dickering) “essentially constitutes the content of economics” (Weber, [1922] 1978, p. 635). Given their predominant significance in markets and economic life, the discussion of prices, for economic sociology, thus becomes “a litmus test for its ability to demonstrate the importance of distinctively social dimensions in the most conventional economic practices” (Yakubovich, Granovetter, and McQuire, 2005, p. 579). This dissertation advances the fledging sociological theory of prices.

The Price Phenomenon and Pricing Practices

There are, roughly speaking, three lines of researches in economic sociology (and social sciences in general) that are relevant to this study on the price phenomenon.[1] The first concerns the qualification and valuation of goods in markets (e.g., Callon, Méadel, and Rabeharisoa 2002; Callon and Muniesa 2005; Fourcade 2011; Muniesa 2012; Stark 2009; Zelizer 1978, 1994, 2004). This line of research addresses (1) whether or not the cultural and moral values of "goods" allow them to legitimately enter market exchange and be attached with prices in the first place, and (2) how goods are qualified and their economic values are assessed by market actors (producers, sellers, buyers, and various intermediaries) through comparison—i.e., establishing similarities and differences among goods—facilitated by various technological, cognitive, social and market devices. Qualification and valuation of products are the aspect of the price phenomenon that has recently received the most attention in economic sociology. However, while the values and valuation of goods analytically constitute the conditions for market exchange and price formation, this line of research usually says little about how, exactly, a specific quantitative price is "translated" from various largely qualitative values (Aspers and Beckert 2012). This issue of translating values into prices is addressed by the other two lines of research, which focus on social mechanisms at market (inter-firm) and organizational (intra-firm) levels, respectively.

The second line of research studies price mechanisms, that is, how factors and forces at the *market and inter-firm* level (such as competition, supply and demand, institutions, and networks) determine price. Price mechanisms have been traditionally the territory of economics and only played a limited role in economic sociology. The third line's research object is pricing practices, i.e., the organizational procedures/processes

[1] See Beckert (2011) and Aspers and Beckert (2012) for more comprehensive reviews of sociological studies on the price phenomenon.

and information employed *within* a firm to reach pricing decisions. Different from price mechanisms, which are active and visible at the market level, pricing practices are hidden behind the boundary of the firm and “occur in the context of an organizational process in which information is gathered, shared, and interpreted” (Ingenbleek, Debruyne, Frambach, and Verhallen 2003).[2] Pricing practices are the least studied aspect of the price phenomenon in economic sociology, but they are by no means the least important (Beckert 2011). Practically, pricing practices concern the organizational profiting capacity of the firm to effectively (or not) reap the economic rents from the values it creates in its products by setting the “right” prices (Dutta, Zbaracki, and Bergen, 2003). Thus, knowledge of pricing practices would have important implications about how a firm can enhance its profiting ability and gain competitive advantage by optimizing its pricing practices. Theoretically, pricing practices together with price mechanisms constitute the two intertwined pathways at the organizational and market levels, respectively, through which values of goods are “translated” into prices.[3] Prices are, after all, set through the “visible hands” of firms and sellers, rather than directly “conjured” by the “invisible hands” of price mechanisms.

This dissertation therefore focuses on pricing practices as the main object of

[2] Pricing practices should also be distinguished from pricing strategies. The latter pertain to price mechanisms; they are the results of market-level forces and usually modeled using game theory. Pricing strategy refers to a firm’s short-term calculative strategy of setting prices to achieve specific market goals (for example, to increase its market share, or to deter the entry of new firms). A price war between two firms is an example of pricing strategy. For a given firm, pricing strategy usually changes often, as it is very responsive to market change. In contrast, pricing practice refers to some more general and stable organizational orientation of the firm; what the concept emphasizes is not the final pricing decision/strategy itself, but what information is routinely used and how information is usually processed and interpreted within the firm for making general pricing decisions (Ingenbleek *et al*. 2003).

[3] There also exists a feedback path from prices to values that closes the loop (e.g., Aspers and Beckert 2012; Fourcade 2011). For example, in some cases, high price itself is interpreted by market actors as also contributing to the high value of the product, not just the other way around. However, this feedback is not discussed here, since price-formation is the focus of the current study.

research, which aims to restore an indispensible, yet “missing,” link connecting the current theoretical focus of economic sociology on values and valuation to the core issue of price formation, and thus would enrich the sociological understanding of the price phenomenon and the functioning of markets in general.

The difference between pricing practices and price mechanisms, however, should not be essentialized. The two are closely connected: price mechanisms at the inter-firm level create the market condition, and they set constraints on pricing practices at the intra-firm level which in turn lead to pricing decisions. Conversely, the aggregation of the pricing decisions made by individual firms through pricing practices reproduce (or reshape) the market contour regulated by price mechanisms. In economics, such connection is typically treated as perfect. For example, in its extreme version (the competitive equilibrium theory), firms are all price takers and thus need not make pricing decisions at all—the price mechanism makes pricing decisions for the firms and *is* the pricing practice itself. However, this perfect connection becomes problematic when one turns to empirical markets—the pricing processes within firms differ in varying degrees from those prescribed by economics (e.g., Hall and Hitch 1939; Dutta *et al*. 2003; MacKenzie, Muniesa, and Siu 2008). [In this sense, pricing practices are potentially an important site where the performativity of economics is manifested, mediated, or resisted, and thus deserve greater sociological attention.]

Such discrepancies result in an unfortunate separation between research on price mechanisms and that on pricing practices, which should be two sides of one coin. The former is mainly conducted in economics, including traditional microeconomics based on the assumption of perfect competition and its variants, and the more real-market oriented field of Industrial Organization, where firms are reduced to passive price takers, bio-automatic imitators, or highly sophisticated game theorists (e.g., Mas-Colell *et al.* 1995; Ania 2008; Tirole 1988).[4] Unlike economics, among the few sociological studies on price mechanisms that treat price as the dependent variable to be explained, most empirically investigate the effects of various social constructs—such as status (Benjamin and Podolny 1999; Podolny 1993), embedded ties and board membership (Uzzi and Lancaster 2004), network size and structure (Baker 1984), industrial categorization (Zuckerman 1999, 2004), and institutional context (Zhao 2008)—on the level or volatility of price in different markets. Despite the valuable insights obtained, these sociological studies have serious limitations. Since the models estimated are regression models, they can only be interpreted as price-association rather than price-determination models. Moreover, in most sociological studies, price is inappropriately isolated from other economic variables, such as revenue, cost, output, and profit. After all, price is only one of an array of inter-related economic variables to be simultaneously determined.

The study of pricing practices is largely confined to the field of marketing research in business schools (e.g. Cressman 2009; Dutta *et al.* 2003; Hinterhuber 2008; Ingenbleek 2007; Ingenbleek *et al*. 2003). This literature also provides important insights. There are, broadly speaking, three different pricing practices (Ingenbleek *et al*. 2003): a) *cost-informed pricing*, i.e., the pricing practices based on a firm's cost information, aiming to cover costs and achieve a target profit margin (see also Hall and Hitch 1939); b) *competition-informed pricing*—the pricing practices in which a firm makes pricing decisions by referring to its competitors' pricing decisions; c) *value-informed pricing,*

---

[4] For defenses and improvements of these (over)simplified assumptions, see, for example, Alchian (1950), Becker (1962), Friedman (1953), and McMillan (2002).

which bases pricing decisions on the unique value of the product (compared with other products in the market) perceived by consumers, and which can be quantified by assessing the amount of money consumers are willing to pay for the product (for example, through survey methods).[5]

Marketing researchers tend to agree that, theoretically, among the three, value-informed pricing is superior, because it is most effective in collecting economic rents from the values created in the products (e.g., Hinterhuber 2008; Ingenbleek 2007; Ingenbleek *et al*. 2003).[6] However, a puzzle haunting this field is that despite the long-time promotion of value-informed pricing by marketing scholars and practitioners, only a small proportion (less than 20%) of firms are using it—the other two pricing practices are still dominant (around 40% each) (Hinterhuber 2008). Marketing researchers usually look for explanations at the organizational level, such as insufficient techniques for value estimation, poor sales force training, and lack of top management support. These answers are unsatisfactory because they focus solely on organizational factors within a firm, largely overlooking the effects of price mechanisms at the market level. The "inertia" of pricing practices may suggest the viability of different pricing practices depends in part on the market environment shaped by price mechanisms, which, if true, further suggests there may be no single universally superior pricing practice that should be recommended

[5] Note that the pricing practices adopted by any firm tend to be a hybrid of the three, but in most cases there is a predominant pricing orientation.

[6] Although Ingenbleek *et al*. (2003) advocate a "contingency approach" to the effectiveness of the three pricing practices and claim "there are no general 'best' or 'bad' practices" (p.289), this "contingency" seems to only undermine but not at all negate the universal superiority of value-informed pricing. In fact, their results even further support its universal superiority: "Unlike cost-informed and competition-informed pricing, we find no situation in which value-informed pricing can be considered 'bad practice.' The overall effect of the simple and interaction effect remains positive or at worst neutral, like in the situation of extreme competition. This confirms conventional marketing wisdom that understanding the customer's value perception is key to successful pricing" (p. 301). This is further discussed in the "Discussion."

to all firms unconditionally.

This puzzle of pricing practices is also pertinent to economic sociology. Value-informed pricing apparently has connection with the literature on qualification and valuation; thus the two literatures may potentially enrich each other, and in particular sociological insights may directly contribute to the resolution of the puzzle. More importantly, the market competition model (or the W(y) model) developed by Harrison White (1981a, 1981b, 2002), one of economic sociology's fundamental works, corresponds to competition-informed pricing, since in the model each firm bases its pricing and output decisions on the information of its competitors' realized prices and sales. According to White, the W(y) mechanism, and thus competition-informed pricing, should prevail in production markets. However, the existence of different pricing practices poses serious challenges to the W(y) model, as only about 40% of firms are actually using competition-informed pricing (Hinterhuber 2008). This challenge is most clearly illustrated by a recent case study of the Burgundy wine market (Chiffoleau and Laporte 2006). Among the thirty one producers in this market, only six adopt pricing methods seemingly matching the description of the W(y) model; fifteen producers can be classified as using cost-informed pricing; about two to five producers employ value-informed pricing;[7] the other five producers are simply price takers.

Then, questions arise: How can one explain the existence of various pricing practices *in the same market*? Among them, is there a universally superior one? If not, what are the market conditions for different pricing practices to prevail?

[7] Chiffoleau and Laporte seem to be unaware of the marketing literature on pricing practices, so there is some ambiguity for my re-classifying the producers into three categories based on the information they provided. But the general picture they depict is quite consistent with the three-category scheme.

To answer these questions, as it should be clear now, a theory is needed that cuts across all three aspects of the price phenomenon—qualification/valuation of goods, price mechanisms, and pricing practices. The strategy adopted here is to build a theoretical model with the viability of pricing practices as the output and various conditions of qualification/valuation and price mechanisms as the inputs, and then by varying the inputs to investigate how the conditions of qualification/valuation and price mechanisms affect the viability of pricing practices. More specifically, this study uses the W(y) model (White 1981a, b) as a starting point and generalizes it to achieve this goal. *The intuition is: where the W(y) model fails implies the possible existence of other pricing practices. Thus, by specifying the conditions under which the W(y) mechanism is nonviable, the conditions under which other pricing practices are viable may be discovered.* Although the model developed herein is based on the W(y) model, prior knowledge of the W(y) model is not necessary for the reader to understand the current model, since this is a fully stand-alone generalization that subsumes White's model as a special case. It also must be emphasized that the viability conditions of the W(y) mechanism to be specified in this study differ from those already discussed by White. The issue to be addressed here is: not all markets (or market segments) judged inhabitable for the W(y) mechanism by White's theory are really inhabitable for the mechanism, as illustrated by the case of the Burgundy wine market.[8] Thus, further conditions are needed for assessing the viability of the W(y) mechanism.

There are several justifications for choosing this strategy. First, the W(y) model

[8] Even if one argues that the Burgundy wine market actually consists of several smaller markets, these sub-markets should have similar market parameters, because they are structurally similar. Hence, they are very likely to be all judged inhabitable for the W(y) mechanism by White's theory, but the mechanism only exists in one of them. The issue persists.

can be seen as some price mechanism—firms' pricing decisions are made within a context of market and inter-firm level economic variables. Thus, starting from the W(y) model can avoid the aforementioned shortcomings of other sociological studies which usually rely on price-association (rather than price-determination) models and inappropriately isolate price from other economic variables. Second, although the W(y) model represents some price mechanism (as the organizational aspects of firms and pricing are assumed away), it has clear implication for the pricing practice associated with it—competition-informed pricing.[9] Third, the model has an explicit component modeling the valuation of products by consumers. Fourth, the model deals with the most prevailing and general type of markets in real economy—production markets, rather than some specific idiosyncratic market (as is the case in most empirical studies). Therefore, the W(y) model provides a convenient midpoint for bridging all three aspects of the price phenomenon.

However, the W(y) model does have limitations. Most importantly, as a static model, it is unable to capture the market dynamics *off* equilibrium—the normal state of markets. As a result, the viability conditions derived by White are only static and thus incomplete. This is the very reason why the W(y) mechanism is much less prevalent than White's theory suggests. To address this issue, an alternative dynamic model, called here

[9] It is true that, in the W(y) model, firms also need their own cost information when making pricing decisions. Yet the predominantly important piece of information is the pricing decisions of competitors, while knowledge of cost information is taken for granted. Thus, the W(y) mechanism unmistakably corresponds to price-informed pricing. Moreover, although the W(y) mechanism and competition-informed pricing are treated here as if interchangeable, they are not identical. First, the W(y) mechanism is, strictly speaking, some price mechanism rather than pricing practice. Second, the pricing practice implied by the W(y) mechanism is a representative of many possible variants pertaining to the category of competition-informed pricing. However, unlike game theoretical models of pricing strategy which are highly sensitive to the specification of game setting, the W(y) model represents nicely the long-term, general, and stable character of the informational aspect of competition-informed pricing. Therefore, practically, this dissertation does not distinguish between the two concepts.

the “price flocking model,” is built to derive the dynamic viability conditions. This model derives its name from the flocking behaviors of flying birds (wild geese, for instance)—as discussed in the first chapter, the two share formal similarities.

Moreover, the W(y) model does not give adequate consideration to uncertainties, which play an important role in the survival of pricing practices—it is shown later that the dynamic viability conditions have much to do with uncertainties. In order to derive the dynamic viability conditions, this study offers 1) formal definitions and measures of a variety of relevant market uncertainties, 2) a fine-grained analysis of the *inter-dynamics* among different uncertainties and the social mechanism at issue (price mechanisms and pricing practices in this case), and 3) a topology of how the viability of social mechanisms may depend on the distribution of different uncertainties. All of these are lacking in the current literature.

Re-conceptualizing Uncertainties

This dissertation also contributes to sociological research on uncertainty. How social order emerges from and sustains under uncertainty has been a unifying theme in sociology (Beckert 1996, 2011; Finch 2007). In the existing literature, there are, roughly speaking, two divergent views. The most common is that uncertainties are “undesirable:” these undermine social actors’ ability to make decisions and coordinate with each other, and thus constantly threat to disrupt social order (or hinder its emergence). Facing various uncertainties, social actors invoke certain social mechanisms or structures—such as norms and institutions (DiMaggio and Powell 1983; Durkheim 1947), hierarchies (Williamson 1975, 1985), networks (Granovetter 1985; White 2002), Status (Podolny

1993, 1994), and calculative devices (Callon and Muniesa 2005)—to reduce uncertainties and impose social order (along this line, see also DiMaggio and Louch 1998; Huault and Montagner 2009; Peterson 1997; Smith 1990; Uzzi and Lancaster 2004; Velthuis 2003; Yogev 2010). The development of the original W(y) model is also motivated by this view of uncertainty: the W(y) mechanism is invoked by producers to reduce uncertainty and impose market order—such order is named by White (2002) the "interface discipline."

In contrast to this "undesirable" picture of uncertainty, a less common view sees uncertainties as "desirable," since the undetermined situations generated by uncertainties suggest opportunities for social actors to break free from the over-determined constraints of social order and to gain profits and advantages through creative agency and innovation (e.g., Knight 1921; Stark 2009; White 2008). These two views of uncertainties correspond to two lines of research in the sociology of markets, the first focusing on various stabilizing processes that impose market order, while the second on market destabilization, innovation, and change (Dubuisson-Quellier 2010; Overdevest 2011).

Regardless of their different focuses, the two views (and the two corresponding lines of research) share the same underlying logic—uncertainties are conceived as destabilizing "factors" that, for better or worse, (potentially) bring about disorder, disruption, and change. However, this picture of the roles of uncertainties in relation to social order is incomplete. This study complements this general picture by showing that uncertainties may well increase the stability and robustness of social order (market order in this case). This is not in the "risk-aversion" sense that uncertainties deter social actors from taking "risky" deviating actions. Rather, uncertainties, conceptualized as some shared cognitive "tolerance intervals" of errors and deviations, are akin to lubricant—

they make the otherwise brittle and friction-fraught system more robust and error-tolerant.[10]

Furthermore, this study provides a novel conceptualization of quality ambiguity—an important kind of uncertainty that has received much attention from both sociologists and economists (e.g., Akerlof, 1970; Lynn, Podolny, and Tao 2009; Peterson 1990; Podolny 1993, 1994; Spence 1974; Velthuis 2003). The problem of quality ambiguity is usually framed as one of asymmetric information, where, for a given product, there is some "true" quality usually known by the seller, but unknown to the buyer. After the buyer uses this product for a while, the "true" quality is revealed. However, such a framing makes sense only when the standards and procedures for evaluating quality are clear and consistent among both buyers and producers. In reality, as is implied by the scholarship of marketing research and the perspective of performativity (e.g., Finch 2010; Kjellberg and Helgesson 2006; Callon *et al*. 2002; Callon and Muniesa 2005), there are ambiguities and discrepancies intrinsic in the standards, procedures, and processes that producers and consumers mobilize to evaluate and compare qualities, individually or collectively. Thus, strictly speaking, there is no single "true" quality; rather, there is only the "fuzzy" distribution of quality. This "fuzziness" is some irreducible uncertainty that confronts *both* producers and consumers.

In fact, cases in which quality ambiguity is shared by actors on both transaction sides have been discussed in sociological studies of particular markets, where the

[10] This view of uncertainty is both related to and different from the organizational literature on loose coupling (e.g. Orton and Weick 1990; Weick 1976). Markets, the social systems discussed here, may be seen as loosely coupled systems in varying degrees. Stability is often associated with loose coupling. According to this literature, it is the structural properties of loose coupling that brings about systemic stability, while uncertainties are largely treated as some "hostile" environment external to organizations. In contrast, it is argued here that uncertainties, as an integral component of loosely coupled systems, may directly contribute to systemic stability.

qualities and values of products are less associated with their direct physicality and thus are obviously collectively negotiated by market actors, for example, markets for fashion (Aspers 2010), arts (Velthuis 2005; Yogev 2010), life insurance (Zelizer 1979), and the natural environment (Fourcade 2011). These studies typically focus on how certain social mechanisms are invoked to reduce quality/value ambiguity and facilitate the formation of a relatively stable and consistent perception of quality/value among market actors. However, the current study suggests that even in well-ordered industrial markets of standardized products, quality ambiguity persists and affects both producers and buyers. Then, what is of theoretical interest is no longer how social mechanisms reduce quality ambiguity and impose market order, but rather the role of the persisting quality ambiguity, as some non-negligible irreducible uncertainty, in the functioning of the social mechanism maintaining market order. This paper takes up this issue in the case of pricing practices.

Methodology

Methodologically (and also substantively, as discussed later on), the current model has close connections with the game theoretical model of status formation (Gould 2002; Lynn, Podolny, and Tao 2009). Lynn *et al.* reformulate Gould's static equilibrium model into a dynamic one and incorporate uncertainty into it, just as what the current study does to the original W(y) model. However, although the skill sets of the two modeling approaches are quite similar, they differ in terms of model assumptions. First, the current model (and the original W(y) model) is *not* a game theoretical one, since it does not share the individualistic micro-behavioral assumptions of game theory; instead, its assumptions are clearly more in line with the sociological tradition of social construction, as explained in greater detail in chapter 1. Second, while the status formation model adopts the economic framework of asymmetric information to approach the issue of quality ambiguity, the current model sees quality ambiguity as some irreducible uncertainty faced by both sides of transaction. Third, whereas the status formation model includes only one kind of uncertainty (quality ambiguity) and treats it as a fixed input, the current model considers four different uncertainties and the inter-dynamics among them.

Dissertation Outline

The rest of this dissertation is organized as follows. Chapter 1 provides an informal formulation of competition-informed pricing (the price flocking model) and other pricing practices. In chapter 2, definitions of relevant market uncertainties—recognitive, predictive, absolute, and relative uncertainties—are given, and their direct implications for the viability of different pricing practices are laid out in four propositions. In chapter 3, a formal "flocking model" of competition-informed pricing is formulated. In chapter 4, two kinds of dynamic instability of competition-informed pricing—off-equilibrium unreliability and vulnerability to disturbance—are demonstrated. It is proved, and illustrated by simulation, that all market settings judged inhabitable for competition-informed pricing by the static W(y) model are subject to the first instability, and some of the settings are subject to the second. Thus, under White's original assumptions, competition-informed pricing is infeasible in virtually all market settings due to dynamic instability. However, the mechanism does exist in quite some real markets or market segments (Chiffoleau and Laporte 2006; Uzzi and Lancaster 2004; White 1981b). To address this contradiction, in chapter 5, one type of uncertainty—quality ambiguity of products—is introduced to the model. It is proved, and illustrated by simulation, that the existence of a certain degree of quality ambiguity can greatly reduce both kinds of dynamic instability, and thus make competition-informed pricing viable under dynamic conditions. In the "Discussion," the viability conditions for all three pricing practices are specified. It turns out that each kind of pricing practice is only viable under certain combinations of levels of different market uncertainties. Supporting evidence from existing studies, theoretical and practical implications of the current study, as well as limitations and future research agendas, are also discussed. The dissertation ends with the "Conclusion."

Chapter 1 An Overview: A Dynamic Formulation of Different Pricing Practices

The problem of elusive market demand faced by firms in an imperfectly competitive market is a major concern of this study, which is shared by economics. However, the former, as a sociological approach rooted in the theoretical tradition of social construction, differs decisively from the latter. The difference lies in their diverging attitudes towards uncertainty. Frank Knight (1921) made a famous distinction between calculable risk and irreducible uncertainty. Risk refers to the situation in which a probability distribution can be assigned to possible outcomes—a version of probabilistic determinism, while in the case of uncertainty, no probabilities can ever be sensibly assigned. In most economic models, however, uncertainties are transformed into risks, largely because risks are far more mathematically tractable than uncertainties. Accordingly, the problem of elusive market demand is usually framed as one of incomplete and/or asymmetric information, and bounded rationality. This framing suggests that the market demand (or its probability distribution), however elusive, is "out there;" the only problem is the unavailability of information, or "data." Thus, the task for game theorists is to put themselves in the shoes of each game player (each firm) and, through cynical speculation on each other's motives and potential actions and/or through certain techniques (signaling, imitation, among many), to reveal the existing market demand and/or equilibrium strategies. To begin with, however, game theorists still have to assume plenty of information about the demand curve (e.g., Rasmusen 2001; Ania 2008; Tirole 1988).

In contrast, the current approach views the problem as one of irreducible uncertainty. Therefore, the task of firms is not to *discover* the existing demand curve(s) (i.e., to get the data), because the complete data simply are *not* out there. Rather, they have to socially *construct* a demand curve (i.e., to make the data, though by no means from nowhere). This formulation of the problem faced by firms is in line with Deweyan pragmatism (Whitford 2002), which would proclaim that the unambiguous preferences of buyers (and thus the clear demand curve) do not exist *before* market transactions—i.e., before firms supply their products to the market, set prices, and consumers make their purchase decisions. That is, in some sense, the demand curve is not something already there but only *revealed* by market transactions; instead, the demand curve is partly *brought into being* by, and *after,* the transactions. This suggests there is always at least a component of the demand curve that is generated by the firms' very market actions (competitively producing, supplying, advertising, and pricing their products), and cannot be determined beforehand. This undetermined component of the demand curve is, obviously, irreducible uncertainty, rather than quantifiable risk.

When this uncertain component of the demand is significant enough, it is nonsensical to assume that firms would base their market decisions on the demand curve or on the revelation thereof, as there is no meaningful demand curve which can be thought of before firms make their market decisions and actions. In such a case, as argued here, the firms would not and cannot directly or indirectly speculate on the elusive demand, nor do they have to retreat to the stronghold of excessive hierarchies, non-rationalistic imitation, or other "extra-market" regulations; rather, they also have the option to collectively construct a shared demand curve by monitoring each other's decisions, actions, and outcomes—this becomes possible and sensible given the fact that the market actions of firms give rise to, instead of depending upon or simply revealing, the market demand. That is, it is the very existence of uncertainty that makes room for the agency of market actors to socially construct and sustain a relatively stable market order, at the same time *without* sacrificing their ability to perform (often "self-interested") economic calculation and becoming complete “slaves” of culture and institutions.

A Dynamic Formulation of Competition-Informed Pricing: The Price Flocking Model

Following White, it is assumed that firms are profit-maximizers. Despite its well-known limitations, this assumption is analytically attractive. First, it naturally and conveniently leads to well-defined equilibrium (or equilibria), if there is (are) any. Second, this assumption, along with the resulting equilibrium, provides a baseline for evaluating the actual behaviors of firms.

However, it has to be emphasized that the firm conceptualized here differs from the (bounded) “rational” agent of the economic theory of the firm, who “believes” in the existence of an entirely exogenous (though perhaps unrevealed) demand upon which it can “rationally” act. Instead, it is more like the Deweyan rational pragmatist whose own market actions would partly bring into being the very conditions (the particular market demand) for those actions. In this sense, the firm modeled here is an agent combining the characteristics of Deweyan pragmatism and the theory of economic performativity, though it is not a pure economic-performative agent, as it does not purposefully enforces the law of any specific economic theory based on completely exogenous market demand.

To maximize profit, a firm needs two pieces of information: its revenue curve $R(y)$ and its cost curve $C(y)$, where y is the output volume of a certain product (the same y as in White’s W(y)), and $R(y)$ and $C(y)$ are the sales revenues and production costs, respectively, corresponding to different levels of y. Thus, the expected profit, defined by $R(y)$ - $C(y)$, could be maximized by choosing an optimal production volume y^*. The associated optimal asking price p^* is determined by $R(y^*)/ y^*$, the expected revenue from selling y^* units of product divided by this optimal volume.[11] Whereas the cost curve $C(y)$ is supposedly known to the firm itself, the revenue curve $R(y)$ is usually unknown, because it is equivalent to the firm's demand curve,[12] which is elusive due to irreducible uncertainty. To solve this uncertainty problem, instead of making extra-assumptions about the demand curves and transforming uncertainties into risks as economists usually do, firms, White argues, construct a shared revenue curve by observing each other's realized sales revenues and volumes. This resulting artificial curve, when settling in static equilibrium, is the famous W(y) curve.

This dynamic process has a zoological analogue—the flocking of migratory birds, say, wild geese. In a flock of flying geese, each bird constantly adjusts its optimal niche in the formation according to (a) the sensed positions of its peers in the air flow (similar to the observed sales revenues and volumes of competing firms) and (b) its own strength and maturity (analogous to each firm's cost structure). The aggregated result of this mechanism is some fluid curvilinear flock formation (akin to the collectively constructed revenue curve $R(y)$). Due to this analogy, the dynamic model of the W(y) mechanism (or competition-informed pricing) constructed here is called the "price flocking model" (or "flocking model" for short). To emphasize its dynamic nature, the W(y) mechanism is sometimes called here the "W(y) flocking mechanism," while the term "W(y) model" is reserved exclusively for White's original static version of the W(y) mechanism.

---

[11] Although this modeling framework adopted by White resembles the economic model of quantity-setting competition (the Cournot model) rather than price-setting competition (the Bertrand model), White's model may be seen as both a price-setting and quantity-setting model. Differing from the Cournot (Bertrand) model, in which once quantities (prices) are set, prices (quantities) are automatically determined and realized by the force of supply-and-demand, price and quantity, in White's view, can be, to some extent, manipulated by firms simultaneously, because there are no unambiguous demand curves in the first place. That is, firms can make both pricing and output decisions according to the W(y) mechanism without knowing the demand curves.

[12] The demand curve describes the relationship between price p and volume y, whereas the revenue curve is about the relation between revenue R and volume y. Note that the three variables—p, R, and y—are not independent, since $R = py$. As long as any two of the three are known, the third is known. Thus, the demand curve and the revenue curve are equivalent.

The flocking model is summarized in figure 1. Suppose there is a market for a certain product, with I competing firms. The product is differentiated among the firms, and these variants are, to a considerable extent, mutually substitutive. First, before making a new run (the t^{th} run, $t = 1, 2, \dots, T$) of output and pricing decisions, each firm i ($i = 1, 2, \dots, I$) collects information about the realized revenues and volumes of its I-1 competitors in the last run (the $(t-1)^{th}$ run),[13] and then plots these data, along with its own, on the "revenue vs. volume" coordinate plane. The data points are represented by crosses in figure 1.

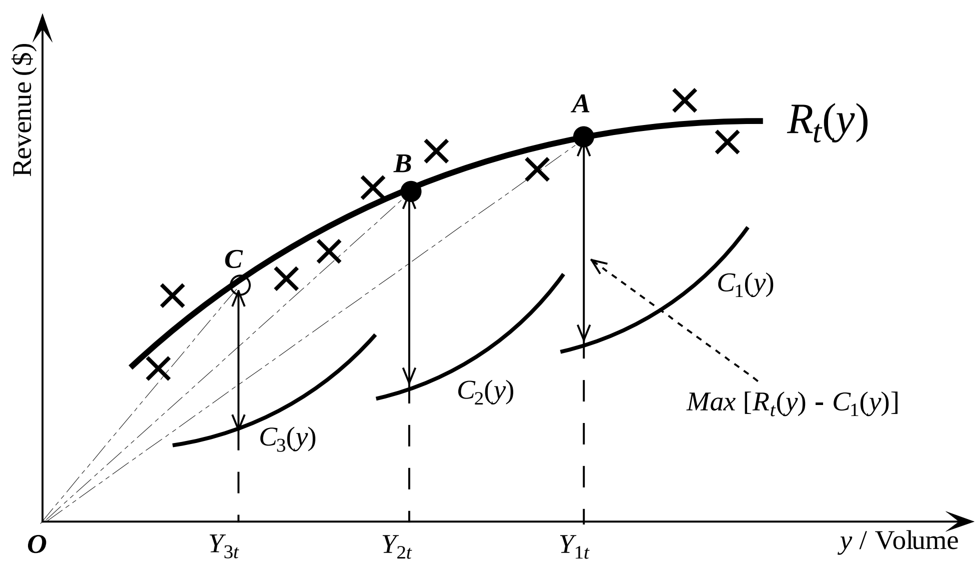

Figure 1: The Flocking Model of Competition-Informed Pricing

Second, each firm uses these observations to fit a regression curve, denoted by $R_t(y)$, with

[13] This actually assumes that the realized revenue and volume of each firm are shared information. This assumption can be relaxed in some ways. For example, each firm may only collect information about several, rather than all, competing firms, and the collected data may be not completely accurate. These relaxations would not change the nature of the W(y) mechanism. Moreover, the assumption of synchronized behavior among firms made here is not necessary for the W(y) mechanism to hold, but it makes the situation simple and facilitates modeling. However, since the pricing and output decisions of firms are modeled here in discrete time, the model does require that firms should not adjust their decisions continuously in time. In reality, firms indeed make their decisions in discrete time, which occurs in the so-called "pricing season" every year (Dutta *et al*. 2003).

the volume y being the independent variable and the corresponding sales revenue being the dependent variable (different from W(y), $R_t(y)$ is off equilibrium; the subscript t denotes the run number). Since the data are the same for all firms, the fitted curve should also be the same, presuming all firms use the same regression model.[14] Then they treat this fitted $R_t(y)$ as their shared revenue curve $R(y)$ in the t^{th} run. The rationale for this reasoning is that each firm believes that a) the market conditions for the new run would not be too different from those for the last run, and b) its product is not too different from those of its competitors, so that it can use its competitors' realized revenue-volume pairs in the last run, along with its own, to *approximate* its own revenue curve in the new run.

Third, each firm i adds below the fitted curve its own cost curve $C_i(y)$, which is assumed to be time invariant. (There are nine firms in figure 1, but only three firms' cost curves are plotted.)

Fourth, the firm i finds the optimal volume, denoted by Y_{it}, by maximizing its expected profit $R_t(y)$ - $C_i(y)$ for the t^{th} run, and then calculates the corresponding expected revenue $R_{it} = R_t(Y_{it})$ (represented by the dots A, B, C, for three firms, respectively, on the fitted curve). The initial asking price p_{it} is set as R_{it} / Y_{it}, equal to the slope of the line from the origin and the dot.

Fifth, the produced volume Y_{it} is sold in the market with some realized revenue R'_{it},[15] which is often different from the expected revenue R_{it}. Then the firms begin the next iteration, etc.[16] This process may settle in some equilibrium, in which case the dynamic $R_t(y)$ curve

[14] Of course, the functional form of the fitted $R_t(y)$ curve may vary across firms, but this would not change the nature of the mechanism.

[15] It is assumed throughout that firms do not keep stocks, i.e., in each run firms would adjust the original asked price ($p_{it} = R_{it} / Y_{it}$) until the entire volume of output is sold out.

[16] Firms in reality need not explicitly conduct any of these calculations. They could just perform some coarse estimation. Allowing this relaxation is crucial, because otherwise the model lacks the generality to represent the loose category of competition-informed pricing. What really matters is: each firm uses the realized outcomes of its

becomes the equilibrium W(y) curve.

It is clear from the description above that the W(y) mechanism is dynamic in nature, but the dynamic aspect cannot be captured by the original static W(y) model focusing exclusively on equilibrium. As the dynamic aspect comes into sight, an ensuing question is whether the equilibria derived by the static model are dynamically stable. Dynamic stability is very crucial because the W(y) flocking mechanism, and the corresponding competition-informed pricing, is practically infeasible if the equilibria are not dynamically stable—just as a ball cannot stay at the peak of a mountain, but can settle down at the bottom of a valley, even though both the peak and the bottom represent equilibrium states.

Value-informed and Cost-informed Pricing

Note that this section is a very coarse description of both value-informed and cost-informed pricing. What it highlights is the informational aspect, that is, the main kind of information the firm bases its pricing decisions on.

Compared with competition-informed pricing, the models of value-informed pricing and cost-informed pricing are much simpler, since both pricing practices are introspective with respect to the focal firm and less oriented toward the dynamic interaction among firms, which, in fact, also largely frees the two pricing practices from the problem of dynamic (in)stability. (Thus, the subscript t for run number is suppressed here in these two models for simplicity.) For value-informed pricing, the cost structure $C_i(y)$ of firm i is taken for granted by the firm, as in the W(y) mechanism. Moreover, it is assumed that a unique and stable revenue curve $R_i(y)$ can also be obtained by firm i through certain means, such as assessing the demand for its products by

---

peers as references to locate its own "niche" in the price hierarchy, just like what each flying goose does in the flock.

surveying its potential buyers.[17] Thus, based on $C_i(y)$ and $R_i(y)$, firm i can conveniently determine its optimal output volume y_i^* and the corresponding optimal asked price $p_i = R_i(y_i^*)/ y_i^*$, as mentioned above. It is clear that value-informed pricing is the one closest to the pricing method prescribed by standard economics, *which entails a very strong condition that the demand of the firm's products is very stable and clear so that it can be relatively easily measured by the firm from its consumers*. If, for example, consumers' valuation of the firm's products is very fluid, or the demand of its product is easily influenced by the pricing and output decisions of the firm's potential competitors, value-informed pricing would become nonviable, because existing methods to directly measure the demand for potential buyers all tend to be very time and resource consuming (e.g., Fourcade 2011), even when the measurement is conducted in a one-shot fashion, let alone in a sustained updating fashion that is required in this case.

For cost-informed pricing, the cost structure $C_i(y)$ of firm i is the main information that is needed for the firm to make pricing decisions. First, the firm i has a habitual output volume y_i that is determined by the producer's experience, rule of thumb, constraints of productive capacity, and historical idiosyncrasies and that only needs small adjustment in each run of production. Second, the corresponding cost $C_i(y_i)$ is obtained. Third, the expected revenue R_i is calculated as $(1+\rho_i)C_i(y_i)$, where ρ_i is some habitual profit rate expected by firm i. At last, the asked price p_i is set as R_i/ y_i.

Immediate Implications for the Viability of the Three Pricing Practices

Before proceeding further, the definition of viability of pricing practices needs to be clarified first. "Viability" here is conceived as a continuum rather than a "viable vs. nonviable"

[17] The demand curve (or the revenue curve) is somehow also equivalent to buyers' valuation function of the firm's products, as demonstrated later on. That is why this pricing practice is called "value-informed."

dichotomy. However, such dichotomous language is used here for convenience. For example, saying a pricing practice is "nonviable" under certain conditions means that firms tend not to adopt this pricing practice, either because following it would be practically infeasible *or* because there are far more efficient alternatives. (Here feasibility is assessed in terms of the implementing difficulty and cost of the pricing practice, and efficiency is assessed in terms of the *relative* profit-reaping capacity of the pricing practice compared with other alternatives.) This implies that saying a pricing practice is nonviable does not rule out the possibility that, in reality, some firm(s) for whatever reasons may use it under those "nonviable" conditions, since it is still practically feasible though a bad choice. Similarly, saying a pricing practice is "viable" means that it is practically feasible *and* its efficiency is, at least, not significantly less than other feasible alternatives. In a word, viability here is defined in terms of both practical feasibility and comparative efficiency.[18] Thus, in a specific market, the three pricing practices might be all practically feasible and have their respective actual follower(s), but they have different viabilities, some being "viable," some being "nonviable."

Moreover, empirical measures of viability, such as the varying prevalence of different pricing practices among the firms under the same market setting, are not usable in the current study, because the individual choices of pricing practices made by firms are not directly modeled, unlike the case of agent-based modeling. Thus, a composite qualitative criterion of viability is needed. Here the most stringent one—the "short board" criterion—is followed, that is, the overall viability of a pricing practice is determined by the factor that makes it least viable. Therefore, as long as a factor renders a pricing practice nonviable, it is nonviable regardless of the value of any other factor.

[18] Note that institutional concerns, such as legitimacy and imitation, are not considered here for the purpose of simplicity. "Second order" factors as such surely need to be included in future theorization.

Among the three pricing practices, cost-informed pricing clearly requires the least amount of information about both demand and competitors, and as obtaining information involves (sometimes astronomical) cost, it also bears the least informational cost. Hence, cost-informed pricing is practically feasible under almost all circumstances, assuming that firms have clear knowledge about their own cost structures. [This does not mean that there is no uncertainty on the supply side of the firms; rather, this assumption suggests that, compared with market demand, the cost structures of the firms are usually less uncertain. At least, after the goods are produced, the costs are largely known—yet this is not the case for market demand and thus pricing.] However, cost-informed pricing is not always viable, because under circumstances when either of the other two pricing practices is also feasible, it is almost always far less efficient in terms of profit-reaping.

Value-informed pricing, while it requires little information about competitors, requires the most amount of information about demand, the obtaining of which is often very costly and even not possible at all. Thus, it is only practically feasible under stringent conditions, as discussed above. However, in those cases where value-informed pricing is indeed feasible, it is usually the most efficient in terms of profit-reaping and thus the most viable.

In contrast, competition-informed pricing requires little information about demand but some about competitors—their pricing and sales results. Although acquiring these results may need some effort, it is usually much easier and cheaper than trying to probe the demand of potential buyers. Moreover, nowadays these results are routinely published by third-party organizations in many well-established markets. Thus, the associated informational cost can be treated as minimal, compared with that of value-informed pricing. When practically feasible, the profit-reaping capacity of competition-informed pricing is far greater than that of cost-informed pricing, though usually not as great as that of value-informed pricing.[19]

Three important results are in order. First, as cost-informed pricing is almost always practically feasible but the least efficient in terms of profit-reaping, it is viable only when both the other two pricing practices are infeasible (as long as either of the other two practices is feasible, cost-informed pricing tends to be nonviable, though still feasible). Second, as value-informed pricing is the most efficient among the three, it tends to be viable as long as it is practically feasible. Third, as a logical result, the keystone to a full mapping of the viability conditions for all three pricing practices lies in the identification of the feasibility and viability conditions for competition-informed pricing. However, such conditions are not that obvious—this is another important reason why this study chooses competition-informed pricing (and the representative W(y) mechanism) as its analytical focus.

[19] For theoretical and empirical results of the relative profit-reaping capacity/efficiency of pricing practices, see Ingenbleek *et al*. (2003) and Chiffoleau and Laporte (2006).

Chapter 2 Market Uncertainties and the Viability of Pricing Practices: Four Propositions

Besides its inability to capture market dynamics, another important limitation of the original W(y) model is its inability to account for market uncertainties. In White's theory, uncertainty on the demand side only plays the role of a trigger to start the W(y) mechanism. Once the mechanism is at work, uncertainty fades into the background and the model looks like a deterministic one. However, the elusive demand is only one of many market uncertainties troubling market actors, and not all relevant market uncertainties recede after the W(y) mechanism is installed. In fact, the W(y) mechanism lives (if viable at all) in an environment fraught with uncertainties, and, not surprisingly, its dynamic viability depends on these uncertainties and the inter-dynamics among them, as illustrated in later chapters. In this chapter, four relevant market uncertainties—recognitive, predictive, absolute, and relative uncertainties—are defined and their implications for the viability of competition-informed pricing (i.e., the W(y) mechanism represented by the price flocking model) and other pricing practices are discussed.

Recognitive Uncertainty

Recognitive uncertainty is the uncertainty that restricts market actors' ability to recognize certain patterns or regularities, and thus also restricts their confidence in the reliability of the recognized patterns or regularities. In the flocking model of competition-informed pricing, high recognitive uncertainty refers to the situation in which the realized revenue-volume pairs of all firms in the market, when plotted on the coordinate plane, look so random that firms cannot fit a meaningful regression curve through them, or have little confidence in the fitted curve if they do fit one. As illustrated in figure 2, the recognitive uncertainty in figure 2a is low, while that in 2b is high.

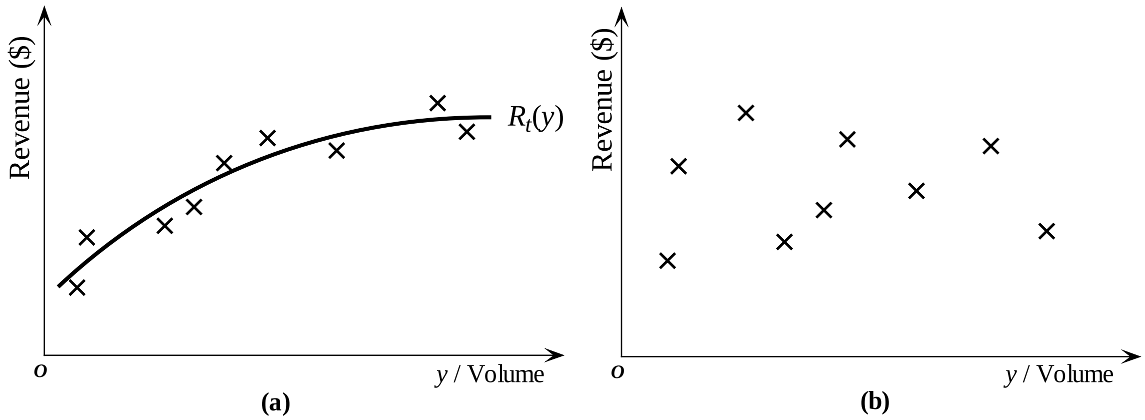

Figure 2: Low and High Recognitive Uncertainty (Adapted from White 1981b, figure 1)

A possible measure of this recognitive uncertainty ($U_{rc.}$) is:

$$U_{rc.} = 1 - R^2, \tag{1}$$

where R^2 is the proportion of variance accounted for by the fitted regression model. When firms are confronted with high recognitive uncertainty, they cannot fit a meaningful $R_t(y)$ curve, or they have little confidence in its reliability, so the W(y) mechanism cannot survive. Similarly, for cost-informed pricing, high recognitive uncertainty means firms cannot acquire definite knowledge of their own cost structures $C_i(y)$ (such cases should be relatively rare), while for value-informed pricing, this means firms cannot obtain a reliable and stable revenue curve $R_i(y)$. This leads naturally to proposition 1.

Proposition 1: The feasibility of competition-informed pricing decreases as the recognitive uncertainty associated with it increases. Competition-informed pricing is nonviable if recognitive uncertainty is too high.[20] This is also true for cost-informed and value-informed pricing.[21]

Predictive Uncertainty

Predictive uncertainty is defined as the uncertainty in the accuracy or correctness of predictions made by market actors, which affects the actors' confidence in the methods used to make prediction. For the price flocking model, one kind of predictive uncertainty is the uncertainty in the expected revenue R_{it} (from selling certain volume of product in turn t) predicted by each firm i (in turn t-1), which is often different from the realized revenue R'_{it}. Two possible measures of this predictive uncertainty of firm i ($U^i_{pr.}$) are:

$$U^i_{pr.} = \sum_{t=1}^{T}\left(R^{'}_{it} - R_{it}\right)^2 / T \text{ , or} \tag{2}$$

$$\text{(\# of wrong predictions by firm } i\text{) / } T, \tag{3}$$

where measure (2) is the sum of squares of differences between the realized and the expected revenues of firm i, from run 1 through run T, divided by T, the total number of runs; measure (3) is the number of wrong predictions (i.e. $R'_{it} \neq R_{it}$, or, against some less strict criterion, R'_{it} differs from R_{it} significantly) made by firm i, divided by T, the total number of predictions by firm i—that is, the proportion of wrong predictions made by firm i. Predictive uncertainty is also meaningful at the market level (the collective of firms), denoted by $U^M_{pr.}$, which has two measures corresponding to those at the firm level:

[20] White (1981b) also noted this point, though he did not formalize and elaborate the idea.

[21] Note that, in a specific market setting, the fact that the recognitive uncertainty associated with the W(y) mechanism (and competition-informed pricing) is high (or low) does not suggest that the recognitive uncertainty associated with cost-informed or value-informed pricing is high (or low) too, because the recognitive uncertainty associated with each pricing practice refers to a different kind of information (cost, value, or competition).

$$U^{M}_{pr.} = \sum_{i=1}^{I} U^{i}_{pr.} / I \,, \tag{4}$$

depending on which measure is used for calculating $U^{i}_{pr.}$. For the price flocking model, when predictive uncertainty is high, especially if the realized revenues deviate *systematically* (i.e., the observed deviations do not seem random) from the predicted ones, firms have low confidence in the method used for prediction, even if they could recognize and fit a sharp $R_t(y)$ curve (i.e., the recognitive uncertainty is low). This result (and the measures of predictive uncertainty) also applies to the other two pricing practices, with the caveat in mind: as the methods used for prediction are different among the three practices, the fact that the predictive uncertainty associated with one practice is high (or low) does not imply those associated with the other two are high (or low) too. This leads to proposition 2:

> *Proposition 2*: The feasibility of competition-informed pricing decreases as the predictive uncertainty associated with it increases. Competition-informed pricing is nonviable if predictive uncertainty in the market is too high, especially when the realized outcomes deviate *systematically* from the predictions. This is also true for value-informed and cost-informed pricing.

Absolute Uncertainty

Absolute uncertainty refers to the uncertainty surrounding the evaluation of some quantity or quality, just as the variance surrounding the mean. One kind of absolute uncertainty that is crucial to and shared by all three pricing practices is the ambiguity inherent in buyers and consumers' evaluation of the quality of the products offered by each firm—the absolute quality ambiguity. Quality ambiguity (or uncertainty) has long been a key issue in both economics and sociology (e.g., Akerlof, 1970; Lynn *et al.* 2009; Peterson 1990; Podolny 1993, 1994; Spence 1974; Velthuis 2003). Most studies approach this issue by first assuming the existence of some intrinsic "true" quality level. Then the issue of quality ambiguity is again transformed to that of asymmetric information, and the way to deal with it is to invoke some social construct (e.g., signals, embedded ties) to channel the needed information and reduce the ambiguity.

However, the current study conceptualizes ambiguity as some intrinsic property of quality (and qualification and valuation in general, see, for example, Aspers and Beckert 2012; Fourcade 2011; Stark 2009 for similar views)—there is no "true" quality; there is only mean quality and the distribution of quality surrounding the mean.[22] Even saying "mean" and "distribution" is some approximation to the ambiguous nature of quality, because these two words imply some underlying probability distribution, but quality ambiguity is some irreducible uncertainty. If this point is admitted, the presumed informational advantage of producers over consumers becomes precarious—a producer may have a better idea about the characteristics and features, either physical or nonphysical, of his/her product, but he/she does not necessarily have a better idea than consumers about what the quality of his/her product is, since the ultimate judge of quality is consumers. Therefore, what the producer can do in practice is, on the one hand, to struggle to design and produce the product according to the elusive quality standards of consumers, and, on the other, to struggle to strategically alter consumers' perception of the product's quality in its

[22] It is important to note that, different from the current literature on qualification and valuation which usually emphasizes the multi-dimensionality of valuation (that is, speaking of "values" instead of value, and "qualities" instead of quality), this study focuses only on a single composite index for the overall valuation of a product, which is called "quality." In other words, "quality" here refers to some generalized quality that subsumes all possible dimensions of valuation (including status). However, the purpose for doing so is merely practical: since the buyer has to buy, or not to buy, the product as a whole (not just one or several of its many features), he/she has to evaluate the product as a whole, including both the relevant physical and non-physical features with status being one of them (this view is also implied in Uzzi and Lancaster 2004). Such an overall evaluation of a product, based on which the buyer decides to buy or not to buy the product, is the "quality" meant here.

own favor (e.g., through advertising).[23]

Speaking of the producer knowing the "true" quality of its product makes sense only when both the producer and consumers reach a complete agreement on the standards for evaluating quality—that is, not only do the consumers know exactly what they want, but also the producer know exactly what the consumers want. The best approximation in reality of this ideal state is, perhaps, an elaborate contract made between a producer and a single customer on a single product tailored for this customer. Even in this case, there may still be the problem of "incomplete contracts," a result of irreducible uncertainty and bounded rationality. Most cases in reality, even in those markets of highly standardized products (like cars and computers), are much worse—the producer does not know exactly what consumers want, and even the consumers themselves do not know exactly what they want.

The ambiguity in consumers' evaluation of quality springs from at least three sources. The first is the variation among the supposedly homogeneous products offered by a single firm. Such variation does not vanish even under standardized industrial procedures. At first glance, this uncertainty seems reducible and may be transformed into risk through statistical methods, such as using sampling techniques to quantify the risk of a defective product. However, this is not the case, as we will see shortly.

The second source concerns the way in which each single consumer makes quality evaluations. Evaluating quality is some generalized calculation (or qualculation, Cochoy 1998) spanning some intermediate range of the cognitive "continuum between qualitative judgment and quantitative (or numeric) calculation" (Callon and Muniesa 2005). To get some sense of the

[23] Thus, there is no gap existing between the "true" quality of a product and the perceived quality by consumers, since there is no "true" quality in the first place; what does exist, however, is the gap between the *expected* perceived quality (distribution) by consumers, from the perspective of the producer when designing and producing the product, and the *realized* perceived quality (distribution) by consumers, after the products meet the consumers.

intermediate nature of this “qualculation,” one need only visit one of the numerous online shopping websites to have a glimpse at the “customer reviews and ratings” section. One could then discover the (implicit) procedure: for a certain product, consumers tend to first isolate a few characteristics and features (both physical and nonphysical) they are most concerned about from the totality of the product, assign different weights of importance to them, judge or rate each of them respectively, and then give an overall quality rating (usually on a scale from 0 to 5) by synthesizing the separate ratings, with varying degree of calculation, elaboration, and patience. Evidently, every step of the qualculation process involves ambiguity.[24] From the perspective of qualculation, the first source of ambiguity, the variation among supposedly homogenous products, involves irreducible uncertainty—it is true that the existence of variation is some “objective” fact, but how the variation is viewed and assessed (such as how to define what is a defective product) by either the producer or consumers is a matter of qualculation with inherent ambiguity.

The third source of quality ambiguity concerns the variation among the quality evaluations made by different consumers and the collective nature of making quality evaluations. Naturally, different customers tend to give different quality evaluations of the same product, and the aggregation of these variations gives rise to the quality ambiguity at the macro-level. However, such aggregation is not a simple integration of independently-made individual evaluations; rather, this is a collective process involving complex interactions among various market actors and devices, for example, producers’ marketing and advertising, retailers’ presentation of the product,

[24] See also Stark (2009) and Favereau et al. (2002). Note that such ambiguity persists even after customers use the product (when they are reviewing it), in contrast to the usual framing (asymmetric information) that customers reveal the true product quality after purchasing it and uncertainty concerning quality vanishes. The existence of this ambiguity is the very reason why every product is subject to qualification and requalification (Callon *et al.* 2002). Whereas Callon *et al.* (2002, 2005) emphasize the calculability of quality through qualculation, here it is the ambiguity inherent in the qualculation process that is underscored. They are two sides of one coin.

third-party monitoring and rating organizations, and the mutual influence among consumers (Callon *et al.* 2002; Callon and Muniesa 2005; Finch and Geiger 2010). The effect of these interactions is to distort—skew, narrow, expand, or shift—the distribution of the otherwise independently-made individual evaluations (Gould 2002; Lynn et al. 2009; Salganik et al. 2006).

The absolute quality ambiguity, in its totality, is the amalgam of all three sources. A natural embodiment of this ambiguity is the variation in consumer quality ratings, just as those on shopping web sites. Measures for the absolute quality ambiguity of firm *i*'s product, denoted by $U^i_{ab.}$, are the variance or standard deviation of quality ratings (assuming there is a "continuous" quality rating variable):

$$U^i_{ab.} = \sigma_i^2, \text{ or } \sigma_i. \tag{5}$$

Since value-informed pricing, as discussed in the previous chapter, relies on both firms and consumers to have clear and consistent valuation of product, it is nonviable if absolute quality ambiguity is too high (because high absolute quality ambiguity leads to high recognitive uncertainty for value-informed pricing, see proposition 1). However, high absolute quality ambiguity would not directly affect the viability of the W(y) mechanism and cost-informed pricing, because these depend little on the demand side information. This gives the proposition below:

> *Proposition 3*: The feasibility of value-informed pricing decreases as absolute quality ambiguity increases. Value-informed pricing is nonviable if absolute quality ambiguity is too high. However, this may not be true for competition-informed and cost-informed pricing.[25]

[25] Different from recognitive and predictive uncertainties in propositions 1 and 2, in a specific market setting, if absolute quality ambiguity is high for one pricing practice, it must be high too for the other two, as it refers to a single kind of information—quality (or value).

Relative Uncertainty

Relative uncertainty refers to the uncertainty in judging the distance or difference between two quantities or two qualities. One kind of relative uncertainty that is relevant to all three pricing practices is consumers' ambiguity in judging the difference between the qualities of products offered by two firms in the same market—the relative quality ambiguity. On the one hand, the existence of relative quality ambiguity relies on the existence of absolute quality ambiguity, since if there is no uncertainty about each of the two quality levels, there would be no uncertainty about the difference between them. On the other hand, the varying individual quality ratings, which constitute the absolute quality ambiguity, cannot be made without comparisons between products offered by different firms, which involve relative quality ambiguity.[26] Note that relative, as well as absolute, quality ambiguity is faced by both the producer and consumers.

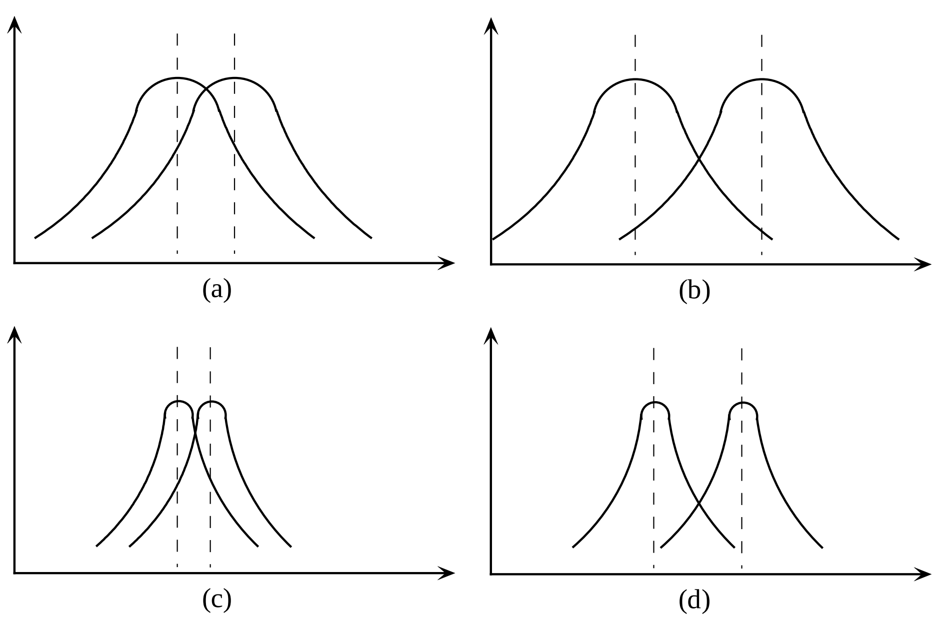

Figure 3: The Absolute and Relative Uncertainties

[26] The dialectics of the absolute and relative quality ambiguities echoes those of "differentiation vs. similitude," or "disentanglement vs. entanglement," (Callon and Muniesa 2005; Finch and Geiger 2010). However, here it is the uncertainty/ambiguity, rather than calculability, that is emphasized.

(Notes: (a) high absolute and high relative uncertainty; (b) high absolute and low relative uncertainty; (c) low absolute and high relative uncertainty; (d) low absolute and low relative uncertainty)

High absolute uncertainty does not necessarily imply high relative uncertainty, because the latter also depends on the distance between the two distributions. Figure 3 illustrates the relationship between the two ambiguities. A measure of the relative quality ambiguity between the products offered by two firms *i* and *j*, denoted by $U^{ij}_{rl.}$, is:

$$U^{ij}_{rl.} = \frac{(\sigma_i + \sigma_j)}{|\mu_i - \mu_j|}, \tag{6}$$

where σ_i and σ_j denote the standard deviations of quality ratings for the products offered by firms *i* and *j* respectively, and μ_i and μ_j denote the mean ratings for the two firms' products. It is clear that the greater the absolute quality ambiguities and the smaller the distance between mean qualities, the higher the relative quality ambiguity. In other words, two quality distributions overlapping too much make it difficult to discern the difference between the two distributions.

Relative quality ambiguity is important to production markets. The ideas of "monopolistic competition" (Chamberlin 1962), "economy of qualities" (Callon et al. 2002), and the W(y) mechanism are all based on the singularity and comparability of products established through differentiation among competing firms. However, high relative quality ambiguity obscures the differences of qualities among products of different firms, and thus undermines the very logic of differentiation. If the relative quality ambiguity in a market is so high that consumers are unable to distinguish between products in terms of quality, then the market would verge on the situation of "pure competition" (Chamberlin 1962). In such a case, all pricing practices based on product differentiation are nonviable, including both the W(y) mechanism and value-informed pricing,[27] but cost-informed pricing would still be viable, since it mainly relies on a firm's own cost information with little ambiguity. This leads to the following proposition:

> *Proposition 4*: The feasibility of competition-informed pricing decreases as relative quality ambiguity increases. Competition-informed pricing is nonviable if relative quality ambiguity is too high. This is also true for value-informed pricing, but not true for cost-informed pricing.

The four propositions in this chapter serve only as a partial guide for further investigating the viability conditions of the three pricing practices. As discussed in the previous chapter, the keystone to a full mapping of the viability conditions of all three pricing practices lies in the specification of the feasibility/viability conditions of competition-informed pricing. However, what is crucial, but missing from these propositions, is the inter-dynamics among the four kinds of market uncertainties. The four uncertainties are not mutually independent if the flocking model is at work: as shown in later chapters, varying the size of the absolute quality ambiguity would cause the sizes of the other three uncertainties to change in different directions, through the dynamics of the W(y) mechanism in a given market. In the following chapters, the size of the

[27] The W(y) mechanism relies on product differentiation because if there is no differentiation in terms of quality, the situation would become similar to that of "pure competition" (Chamberlin 1962). In other words, it is similar to one of oligopolistic competition with no product differentiation, in which, due to the pressure of "pure competition," the profit of the firm would be driven down toward zero, or equivalently, its revenue would be driven down toward cost. Thus, in pure competition, paradoxically, information of cost, rather than information of competitors, would become predominantly important. As a result, cost-informed pricing, rather than competition-informed pricing, would prevail (see also Tirole 1988). Value-informed pricing is based on the "unique" value of the product (compared with products offered by other firms) perceived by consumers, which, of course, also depends on quality differentiation. If relative quality ambiguity is high, the quality differentiation is obscured. This means that the demand of the focal firm's products can be easily influenced by its competitors' pricing/output decisions, which makes the demand elusive and, as a result, leads to high recognitive uncertainty. According to proposition 1, high recognitive uncertainty makes value-informed pricing also nonviable.

absolute quality ambiguity is treated as the only independent variable and the other three uncertainties are treated as intermediate variables. By varying the size of the independent variable, the resulting changes in the intermediate variables can be investigated, so that the final outcome—the feasibility/viability conditions of the W(y) flocking mechanism—can be derived with the assistance of the four propositions.

A remaining technical question is how to mathematically model uncertainty. The approach adopted here is to use probability distributions to *approximate* the properties of uncertainty, since the techniques dealing with probabilities are well-developed and easy to understand. Although this approach involves probabilistic modeling, it does *not* convert the issue of uncertainty into one of risk, because all of the parameters and information concerning the assumed probabilistic distributions are "concealed" from the main market actors—the competing firms—and cannot be used in their decision making.

Chapter 3 A Formal Flocking Model of Competition-Informed Pricing

In order to investigate the dynamics among different market uncertainties (defined and discussed in the previous chapter) and the dynamic feasibility/vaibility of competition-informed pricing, a formal price flocking model, based on White's static model, is developed in this chapter. There are two major improvements. First, the four kinds of market uncertainties, largely ignored in the static model, are explicitly modeled and brought into focus. Second, to examine the dynamics leading markets into or out of equilibrium, the W(y) flocking mechanism is modeled as a Markov-like iterative process. That is, it is assumed that firms base pricing and output decisions in iteration t only on market information in the last iteration t-1, while ignoring information in earlier iterations (1, 2, …, t-2). Adopting the Markov-like assumption does not mean that it is the only or best way to model the W(y) dynamics—other modeling alternatives incorporating information of earlier iterations are readily at hand (e.g., some version of Bayesian updating). However, there are several reasons for choosing the Markov-like model. It is technically simple and easy to understand. As long as it is sufficient to describe the major aspects of the phenomenon, a simpler model is always preferred. Moreover, it is consistent with the spirit of the original W(y) model. Under the irreducible uncertainty of elusive demand, market information in the past quickly becomes outdated and useless, and the Markov-like assumption captures this situation. Third, examining the conditions under which the Markov-like assumption becomes unacceptable could provide some assistance in looking for the (in)feasibility conditions of the W(y) flocking mechanism.

One more caveat: in later chapters the variable price may sometimes seem to be missing from the model, but, as mentioned before, price is implied by other variables in the model.

Absolute and Relative Quality Ambiguities

Now consider a market of a certain product consisting of I competing firms. Each firm i ($i = 1, 2, \ldots, I$) produces the product with some quality distribution N_i (N_i can also be interpreted as a random variable). Figure 4 illustrates the quality distributions for all firms. Suppose N_i follows a normal distribution with mean n_i and standard deviation σ, where $n_i > 0$, and $\sigma << n_i$ (so that the probability of getting a negative quality rating is almost zero),[28] and $n_1 < n_2 < \ldots < n_I$. That is, to make things simple, the absolute quality ambiguity $U^i_{ab.}$ (see equation 5) is assumed to be equal for all firms:

$$U^i_{ab.} = U_{ab.} = \sigma, \text{ for all } i. \tag{7}$$

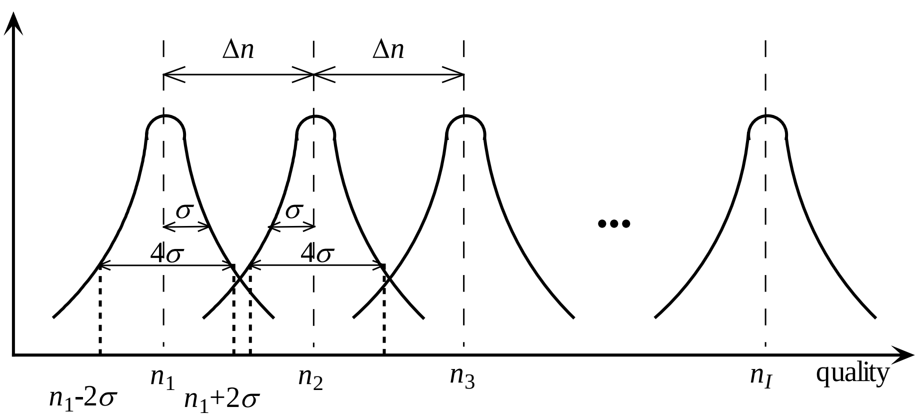

Figure 4: Quality Distributions of All Firms

Note that in the original W(y) model (White 1981a, b), each firm's product has an

[28] The reason for making this stipulation is that the original W(y) model restricts the range of quality n to $[0, +\infty]$, so letting $\sigma << n_i$ could make the current model practically consistent with the original one. A more mathematically appealing approach is to assume N_i follows a Log-normal or Gamma distribution, but the normal distribution is practically simpler. Simulations have also been run under the Log-normal and Gamma assumptions, which show no substantive difference in results.

unambiguous quality level n_i, which differs from the current model. For ease of exposition, it is further assumed that the mean qualities of all firms are evenly spaced with the same distance Δn, i.e., n_i - n_{i-1} = Δn (for i = 2, 3, …, I), so that the relative quality ambiguity between any two firms with neighboring mean qualities, according to equation (6), is the same:

$$U^{i(i-1)}_{rl.} = \frac{(\sigma_i + \sigma_{i-1})}{|n_i - n_{i-1}|} = \frac{2\sigma}{\Delta n}, \text{ for } i = 2, 3, \ldots, I. \tag{8}$$

The assumptions of uniform absolute and relative quality ambiguities can easily be relaxed. However, doing so would not change the nature of the model, only make it more complex.

Consumers have some sense of the means and dispersions of the quality distributions, gained from their own experiences and observation of each other's judgments and ratings. Thus, if a representative consumer sees a particular quality rating of a firm's product too far away (either too high or too low) from the average rating, he/she would discard the rating as abnormal. This suggests that consumers have some sense of the "normal range" of each firm's product quality, which can be modeled by truncating the two tails of the normal distribution. In the current model, such "normal range" (*N.R.* for short) is set as:

$$N.R. = (n_i - 2\sigma, n_i + 2\sigma), \tag{9}$$

that is, about 95% of all ratings of the firm's product would be included in this interval as "normal" ratings. In other words, typical consumers believe that the reasonable quality of the firm's product would not fall out of this interval; therefore, this interval may also be interpreted as the confidence interval for the firm's product quality. Of course, this somewhat arbitrary interval can be set with other sizes, but doing so would not make any qualitative difference.

Consumers' Valuation Functions

Consumers' valuation of a firm's total output (not just the evaluation of its quality) is defined as the amount of money consumers, in aggregate, are willing to pay for buying the entire volume of the firm's output. Such valuation, denoted by V, depends on two independent variables: the volume of the firm's output y and the quality of its product N_i. The larger the volume and the higher the quality, the more money consumers in aggregate are willing to pay for the volume. Adapting from White (1981b, p.521, eq. 2, and p. 525, eq. 4), the valuation function for firm i's total output is specified as:

$$V(y;\, N_i) = \frac{ry^a N_i^b}{\theta}, \quad \text{with } r,\, a,\, b > 0,\ \theta \geq 1, \text{ and } N_i \in (n_i - 2\sigma,\, n_i + 2\sigma), \tag{10}$$

where r is a positive scalar, a and b determine the sensitivity of consumers' valuation to changes in volume and quality, respectively, θ represents the "discount" consumers uniformly impose on all firms (since consumers usually do not want to pay in full for the value of the product),[29] and N_i is a random variable within the "normal range" of firm i's product quality, following the normal distribution with mean n_i and standard deviation σ (but its two tails are cut off).

The valuation function (10) has a linear equivalent. Notice that all three variables V, y and N_i are positive real numbers. Thus, a natural transformation (as in regression analysis) is the *log* transformation. Taking the logarithm of both sides of equation (10) leads to:

$$\log V(y;\, N_i) = a \log y + b \log N_i + \log(\frac{r}{\theta}). \tag{11}$$

[29] The "discount" parameter θ may be time-varying. For run t, the "discount" (now denoted by θ_t) can be modeled as $\theta_t = \max\{\theta_{1t}, \theta_{2t}, \ldots, \theta_{It}\}$, where $\theta_{it} = ry_{it}^a n_i^b / R_{it}$, for $i = 1, 2, \ldots, I$. The numerator of the fraction is the "*undiscounted*" (average) value of firm i's product with volume y_{it} (see eq. 10), and the denominator R_{it} is the total price the firm asks for this volume. Thus, θ_{it} represents the "discount" offered by firm i, and consumers choose the greatest "discount" from all θ_{it}'s to impose uniformly on all firms, which becomes θ_t. In this way, the price competition among firms is captured. However, as made clear later, the current model focuses on *near-equilibrium* dynamics, so θ_t is fixed at its equilibrium value θ (to be set as a simulation parameter) for the sake of simplicity. That is, it is assumed that the dispersion among all the "discounts" offered by firms is small enough (relative to relative quality ambiguity) so that consumers do not take seriously the differences among the "discounts." This assumption is also in line with the logic of monopolistic competition and product differentiation.

That is, log V is a simple linear combination of log y and log N_i. Other model specifications are also possible, but the main results are robust (White 1981a).

A salient difference between eq. (10) and White's valuation function (1981b, p.521, eq. 2) is that the latter has an unambiguous quality n, while the current function has a random variable N_i representing the absolute quality ambiguity.[30] A result of introducing this ambiguity is that the originally sharp valuation curves now becomes "fuzzy" valuation bands. The "central" (modal, actually) line of each band is $V(y, n_i)$, and the two boundaries of the band are defined by $V(y; n_i+2\sigma)$ and $V(y; n_i -2\sigma)$. As σ decreases to zero, the bands collapse into White's valuation curves again. Figure 5 illustrates the valuation bands for three firms with quality distributions N_1, N_2, N_3, respectively.

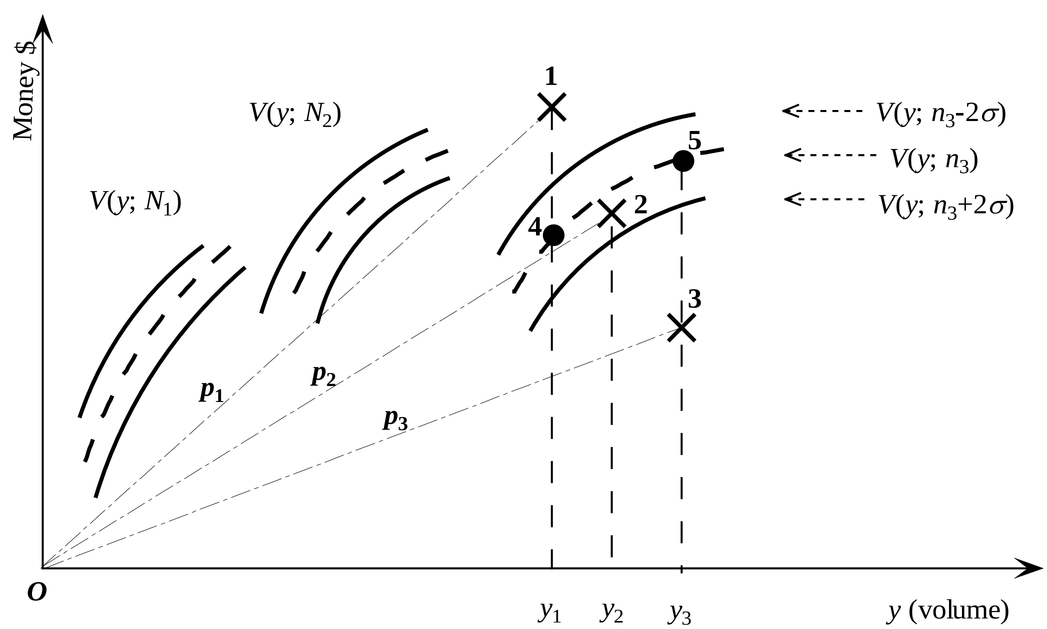

Figure 5: Consumers' Valuation Bands

[30] Another difference is that eq. (10) introduces the "discount" θ into the valuation function. However, this is not a real difference, since eq. (10) can be seen as a combination of White's two functions (1981b, p.521, eq. 2, and p. 525, eq. 4), that is, $V(y; n) = S(y; n) / \theta$.

Now suppose the firm with quality distribution N_3 makes an offer to sell volume y_1 at price p_1, represented by point 1 in figure 5. Consumers will not accept this offer, because it falls outside the valuation band. Since point 1 is above the band, consumers would think that the unit price p_1 (the slope of the line linking the origin and point 1) set by the firm is too high for the "normal range" of its product quality. It is stipulated here that, in such a case, consumers would pay the amount corresponding to the mean quality, i.e., $V(y_1; n_3)$, for the volume y_1.[31] The realized transaction is represented by point 4. If the firm's offer is point 2, consumers would accept that offer, because it falls within the valuation band, suggesting that the unit price p_2 matches the "normal range" of its quality. If the firm's offer is point 3, consumers would perceive that the unit price p_3 is too low for the normal range of its quality. Of course, consumers would not pay more than that offered by the firm, but the firm would soon discern the unusually high demand from consumers, and raise the unit price to increase profit. It is again assumed that the realized payment by consumers is that corresponding to the mean quality, i.e., $V(y_3; n_3)$, represented by point 5.

It must be emphasized that the valuation function is only a quantitative *approximation* of the consumer's behavior. In reality, consumers do not know the value of any model parameters; they do not even know the value of the mean quality and the standard deviation, let alone the specific "normal range" of the quality. However, consumers do have some sense of the average quality and its dispersion, and they do calculate—they perform generalized calculation, or qualculation (Callon and Muniesa 2005). The valuation function (10) is aimed at quantitatively

[31] Of course, there are alternatives to this stipulation. For example, it could be assumed that consumers pay the amount corresponding to the boundary quality (either the lower or upper bound). Or, the consumers could pay some random amount distributed between the lower and the upper bounds. However, these alternatives would not change the nature of this model.

capturing and describing the major properties of this qualculation process through introducing the absolute quality ambiguity σ as a model parameter: in market settings with small σ, consumers' qualculation behavior is closer to quantitative calculation, while in settings with large σ, consumers' qualculation verges on qualitative judgment.

Naturally, it is even harder for firms to assess consumers' valuation functions—that is the irreducible uncertainty in the elusive demand of consumers. If they could, they would be able to implement the most favorable value-informed pricing, since they would know exactly how consumers valuate their products. This scenario, as is shown in later chapters, is not impossible.

Firms' Cost Curves

Following White (1981b, p. 521, eq. 1), the cost curve/function for firm i is specified as:

$$C(y; n_i) = qy^c / n_i^d \text{, with } q, c > 0, \tag{12}$$

where q is simply a positive scalar; c, d determine the sensitivity of the firm's cost to changes in volume y and mean quality n_i, respectively. Different from White's original cost function where n stands for an unambiguous quality level, here n_i stands for the mean of the quality distribution N_i.

Also note that, in contrast to the consumers' valuation function (10), there is no random term in the cost function. The reason is there is far less ambiguity in firms' cost structure than in consumers' valuation. In practice, each firm i, supposedly, should be clear about its costs corresponding to various volumes of output. Thus, the firm could easily fit a cost curve in some functional form, such as

$$C_i(y) = A_i y^{c_i}, \tag{13}$$

where A_i and c_i are the only two regression parameters to be estimated. The firm need not know anything else. The cost function (12) is specified from the perspective of a researcher, who wants to find a common structure for the cost curves of all firms in the market—a matter irrelevant for individual firms. If the researcher's model specification is good enough, as is assumed hereafter, he/she would have

$$A_i = q/n_i^d \text{ and } c_i = c, \text{ for all } i, \tag{14}$$

which can be easily derived by comparing eqs. 12 and 13.

It is assumed that the cost curves are private information, that is, each firm only knows its own cost structure but has no accurate information about those of the others.

Fitting the Revenue Curve and Measuring Recognitive Uncertainty

The foregoing model specifications (eqs. 7 to 14) are all assumed to be time-invariant, including the quality distribution of each firm's product, consumers' valuation structure for each firm's product, and each firm's cost structure. From now on, the modeling proceeds to the dynamic stage.

Now suppose the I firms in the market are about to make pricing and output decisions for the t^{th} run (t = 1, 2, …, T) of production. It is assumed here that the flocking model has already been at work, so all firms follow its rule. Since each firm i has obtained its cost curve (eq. 13 with $c_i = c$ and $A_i = q/n_i^d$), the other piece of information the firm needs is the collectively constructed revenue curve for the t^{th} run—$R_t(y)$. Thus, under the Markov-like assumption, each firm plots the realized sales revenues and volumes of all firms in the (t-1)$^{\text{th}}$ run, denoted by $w'_{i(t-1)}$ and $y'_{i(t-1)}$ (i = 1, 2, …, I)—on the coordinate plane, and fits a curve through them with the functional form:

$$R_t(y) = B_{0t}\, y^{B_{1t}}, \text{ or in linear form:} \tag{15}$$

$$\log R_t(y) = B_{1t}\left(\log y\right) + \log B_{0t}\,, \tag{16}$$

where B_{0t} and B_{1t} are the two regression coefficients to be estimated, and the subscript t suggests that they vary across time.[32] A measure of the involved recognitive uncertainty U_{rc} can be obtained with eq. 16 by computing the corresponding $1 - R^2$ (see eq. 1).

Making Output and Pricing Decisions

With the fitted revenue curve $R_t(y)$ and the cost curve $C_i(y)$ at hand, each firm can now calculate the optimal output volume y_{it}^*, and the corresponding expected revenue $R_t(y_{it}^*)$, and the corresponding unit price $p_{it} = R_t(y_{it}^*) / y_{it}^*$ that maximizes the expected profit $R_t(y) - C_i(y)$. To find the optimal volume y_{it}^*, each firm i could use the equation below derived from the first order condition for maxima:

$$\frac{d}{dy}\left[R_t(y) - C_i(y)\right] = \frac{d}{dy}\left(B_{0t}y^{B_{1t}} - A_i y^{c_i}\right) = B_{0t}B_{1t}y^{B_{1t}-1} - A_i c_i y^{c_i - 1} = 0, \tag{17}$$

where the first equation follows directly from eqs. 13 and 15; B_{0t} , B_{1t} , A_i , and c_i are all regression coefficients estimated by the firm, but, as mentioned before, the researcher knows that $A_i = q/n_i^d$ and $c_i = c$ (eq. 14). Since it is assumed that the W(y) flocking mechanism has been at work, one need not worry about the second order condition; in fact, the current market is assumed to satisfy all the static viability conditions derived by White, that is, this market falls within one of the three viable regions in White's market parameter plane (1981b, p. 527, fig. 3). Thus, the optimal volume y_{it}^* can be obtained by solving equation 17 for y, and substituting in equation 14, giving:

$$y_{it}^* = \left(\frac{A_i c_i}{B_{0t}B_{1t}}\right)^{1/(B_{1t}-c_i)} = \left(\frac{qc}{B_{0t}B_{1t}n_i^d}\right)^{1/(B_{1t}-c)}. \tag{18}$$

[32] Eqs. 15 and 16 are actually equivalent to the functional form of the W(y) curve derived by White (1981b, p.525, eq. 5) with the integration constant k set to zero. As White (1981a, p.22) points out, the value of k has "no substantive significance."

One could then obtain the corresponding $R_t(y_{it}^*)$ and p_{it}.[33]

In order to model the various random errors involved in the actual process of data collection and calculation performed by the firms, and their possible (random) tendencies to deviate from the profit-maximization norm, now assume that the final calculated "optimal" volume, denoted by Y_{it}, and the corresponding expected revenue, denoted by R_{it}, are in general different from the true optima y_{it}^* and $R_t(y_{it}^*)$:

$$Y_{it} = y_{it}^* + \varepsilon_{it}\,, \tag{19}$$

$$R_{it} = R_t(y_{it}^*) + \delta_{it}\,, \tag{20}$$

where ε_{it} is some random error normally distributed with mean 0 and standard deviation $0.05y_{it}^*$, and δ_{it} is also some normally distributed error with mean 0 and standard deviation $0.05R_t(y_{it}^*)$. That is, with about a 0.95 chance, the final decisions of output volume and expected revenue would deviate from the true optimal values no more than 10%. It is further assumed that the error terms are all independent, for all i and t.

Realized Market Outcomes and Predictive Uncertainty

Now each firm i makes an offer to consumers, asking R_{it} dollars for the produced volume Y_{it}, with unit price $p_{it} = R_{it}/Y_{it}$. Let y'_{it} and R'_{it} be the final realized volume and revenue, respectively. Under the assumption that firms do not keep stocks, one has $y'_{it} = Y_{it}$. However, the value of R'_{it} depends on whether the offer (Y_{it}, R_{it}) falls within consumers' valuation band (see figure 5). If the offer falls in the valuation band, one has $R'_{it} = R_{it}$; otherwise, $R'_{it} = V(Y_{it}; n_i)$ (see eq. 10 and figure 5). Now the firms finish the t^{th} run, and then proceed to the $(t+1)^{\text{th}}$ run, so on so

[33] It must be noted that firms need not explicitly perform these calculations. For example, as Leifer (1985) points out, what the firm needs is a pen, a ruler, and a piece of paper to draw the curves and then use the ruler to find the maximum. And in fact, such a process may be some qualculation that is even coarser.

forth. The associated predictive uncertainty can be measured by eqs. (2), (3), or (4).

The flocking model of competition-informed pricing not only captures the dynamics and various market uncertainties, but also takes into account firms' behaviors that deviate from the profit-maximization paradigm. It can be proved that the static W(y) model is a special case of the current model, with the absolute quality ambiguity σ and disturbances (ε_{it}'s and δ_{it}'s) all set to zero, and $Y_{it} = Y_{i(t-1)}$ for all i and for at least one $t \in \{1, 2, \ldots\}$.[34] That is, given there is no quality ambiguity, and no disturbances, as long as the W(y) flocking mechanism steps into equilibrium once, it will be locked in forever, and the fluctuant $R_t(y)$ curve rigidifies into the static W(y) curve.

However, in the next chapter, the situation under investigation is: there is no quality ambiguity, but there are disturbances (i.e., ε_{it}'s and δ_{it}'s are not zeros). Then the dynamic stability of the flocking model is studied. As one will see, the mechanism is unstable, and thus practically infeasible (and nonviable).

---

[34] Note that the current model is still a simplified version of the W(y) mechanism, since the market saturation parameter γ and the "exploitation" ratio τ (White 1981a, b, 2002) are not included. A major function of these two parameters is to determine the equilibrium "discount" parameter θ. Because θ is included in the model, the effects of γ and τ are also partly taken into account. A more sophisticated dynamic model which includes the two parameters has also been developed, and simulations show that the results presented in this paper, which are obtained from the current model, can also be replicated from the more complex model. Thus, the current model suffices for the purpose here.

Chapter 4 Dynamic Instability

Throughout this chapter, the absolute quality ambiguity σ, as is in the original W(y) model, is assumed to be zero; as a result, the relative quality ambiguity is also zero (see eq. 8). However, disturbances (the error terms, ε_{it}'s and δ_{it}'s, in eqs. 19 and 20) are kept in the model. Thus, here the task is, in the absence of quality ambiguity, to examine the dynamic robustness of the flocking model to these disturbances ubiquitous in markets, with the guidance of propositions 1 and 2.

In this chapter, it is shown that the W(y) mechanism is subject to two kinds of dynamic instability—the off-equilibrium unreliability and vulnerability to disturbance. To better illustrate these two concepts, two numerical simulations under corresponding market settings are first provided, then followed by theoretical explanations. Note that all the simulations in this dissertation assume that at time $t = 0$ the W(y) mechanism is in equilibrium, only in subsequent iterations do disturbances keep pulling it away from equilibrium. That is, this study only investigates the near-equilibrium behavior of the W(y) flocking mechanism, to see, after the mechanism is pulled off equilibrium, if it will stably fluctuate around the equilibrium or further slide away from the equilibrium towards breaking down.

Off-equilibrium Unreliability

A necessary condition for the flocking model to survive is that the fitted revenue curves $R_t(y)$ must provide reasonably good predictions, for the firms, of the sales revenues corresponding to various levels of output, since this is exactly what the name "revenue curve" suggests. In other words, the predictive uncertainty of the $R_t(y)$ curves cannot be too high (proposition 2); otherwise, the firms would lose their confidence in its reliability as their revenue curve. If the W(y) flocking mechanism is in equilibrium, there is no such problem, because the W(y) curve (the $R_t(y)$ curve in equilibrium) would provide perfect prediction of the firms' sales revenues, and thus the W(y) curve itself would be perfectly reproduced by the realized outcomes—this follows from the very definition of equilibrium. However, once the W(y) mechanism is perturbed by disturbances and leaves equilibrium, firms have to face the problem of predictive uncertainty. In such a case, as it turns out, firms would find that the realized sales revenues tend to deviate *systematically* from those predicted by the $R_t(y)$ curves, and thus deem the curves unreliable. This off-equilibrium unreliability of the W(y) flocking mechanism is illustrated by the following simulation.

Table 1: Simulation Setting 1

MARKET PARAMETERS							SIMULATION PARAMETERS		
a	*b*	*c*	*d*	*θ*	*r*	*q*	# of Firms (*I*)	Range of Mean Quality.	# of Runs (*T*)
0.8	1	1	-2	9.78	150	1	9	[5.5, 9.5]	50

Consider a market setting adapted from the U.S. cement market in White (1981b, p. 530).[35] The market parameters used in the simulation are listed in table 1. The simulation settings in this dissertation are all based on the examples in White (1981a, b), all satisfying the static viability conditions he specified. For all the simulation parameter settings, there are three places different from White's parameters: first, the value of the scalar *r* in consumers' valuation function (eq. 10), second, the "discount" θ, and third, the number of firms and their quality levels.

[35] The cement market is in the "grind" region, one of the three viable regions for the W(y) mechanism specified in White 1981b, p. 527, fig. 3. The other two regions are named "crowded" and "paradox."

The main purpose of making these changes is to let the ranges of data across different simulation settings become more comparable, facilitating comparison and graphic presentation. Note that, according to White's theory, these changes would not affect the viability properties of the W(y) mechanism.

The number of firms in the market is set to nine for all simulations. This somewhat arbitrary number results from the trade-off between two considerations. On the one hand, if there are too few firms in the market, there would not be enough data points to reasonably assume all firms fit the curve with the same specific functional form.[36] On the other hand, if there are too many firms in the market, it is unreasonable to assume each firm will treat all the other firms as its immediate competitors and keep tracking the information on all of them.

The initial state of the simulation at time $t = 0$, as mentioned before, is the equilibrium state, so the initial sales revenue and volume of each firm can be easily obtained from the static W(y) curve (White 1981a, p. 20, eq. 15, with K set to zero). Fifty iterations are run in the simulation, i.e., $t = 1, 2, \ldots, 50$. The simulation results are shown in figure 6. The expected/predicted sales revenue-volume pairs (the X's) and realized pairs (the dots) of three firms (with respective qualities n_1, n_2, n_3), along with the static W(y) curve, are plotted.

It can be seen from figure 6 that, under the condition of no quality ambiguity, the realized outcomes deviate *systematically* from the predicted ones. In fact, the realized outcomes reveal a unique revenue curve, embodied by the dots, for each firm. These revealed revenue curves, differing from both the W(y) and $R_t(y)$ curves, turn out to be the consumers' valuation function $V(y; n_i)$ (eq. 10). The predictive uncertainty of the W(y) mechanism, measured with eqs. 3 and 4,

[36] In fact, the W(y) mechanism can exist in a market with as few as three firms. Even if the firms use different functional form to fit the curve, this would only add more disturbances to the dynamics but not change the nature of the mechanism. So here the consideration of the number of firms is only for the purpose of making the assumptions of the current model, not the mechanism in general, more plausible.

is 1. That is, no firm at all ever makes a single correct prediction using the W(y) mechanism. More importantly, as long as the firm keeps record of its realized outcomes in each run, it would discover the systematic deviation and find its real revenue curve embodied by the dots. In this case, the Markov-like assumption becomes unreasonable, because the realized outcomes reveal such strong regularity that it is hard to imagine firms would continue to behave as if they are "memoryless." Thus, according to proposition 2, the flocking model (or the W(y) mechanism) cannot survive.

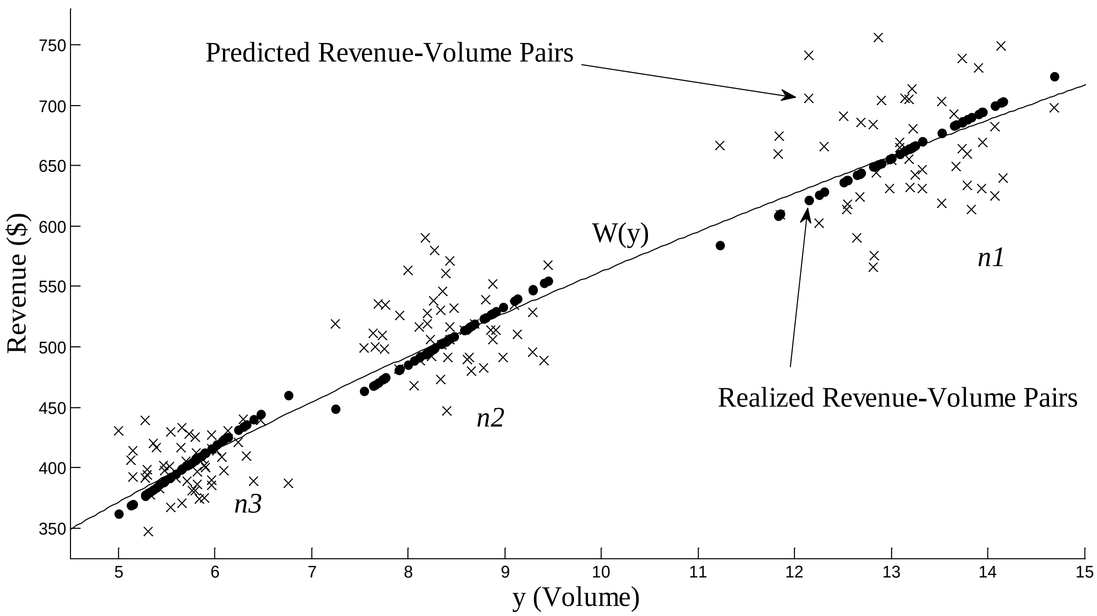

Figure 6: Off-equilibrium Unreliability of the Flocking Model (the W(y) Flocking Mechanism)

It can be further shown (but not shown here) that *this problem of off-equilibrium unreliability prevails in all market parameter settings judged inhabitable for the W(y) mechanism by White's static model, that is, all three viable regions in White's topology* (White 1981b, p. 527, fig. 3). The cause for the off-equilibrium unreliability of the W(y) mechanism is the low absolute quality ambiguity. Low absolute quality ambiguity suggests that the demand of consumers is no longer that elusive—at least, it can be partly revealed by the firms through repeated trials. In such a case, firms do not need to collectively construct some approximated revenue curve, since they have a more accurate alternative—the revealed ones. Then, they could perform profit-maximizing calculation based on these revealed revenue curves, and this scheme is the very essence of value-informed pricing and monopolistic competition. When the absolute (and relative) quality ambiguity is low, the products offered by competing firms are almost perfectly differentiated, and the consumers' demand is also almost perfectly segmented, so that the firm can relatively easily estimate its revenue curves through probing the unambiguous valuation of its product made by its segment of consumers. This leads to the two conclusions below:

Conclusion 1: value-informed pricing is feasible and most efficient, and thus viable, if the absolute quality ambiguity in the market is very low (i.e., σ is close to zero).

Conclusion 2: If the absolute quality ambiguity in the market is very low (i.e., σ is close to zero), competition-informed pricing is unreliable in prediction (high predictive uncertianty) and much less efficient than value-informed pricing, and thus nonviable.

If all firms in the market are performing value-informed pricing, a new (equilibrium) market profile, called here the R(y) curve, may result, and this R(y) curve is very similar to the W(y) curve in terms of shape and functional form (see the detailed derivation of the R(y) curve in appendix A). Thus, cross-sectional market data, as those used in White (1981b), are not sufficient to distinguish the W(y) mechanism from the R(y) mechanism in empirical markets.

This implies that at least some empirical markets identified by White (1981b) as following the W(y) mechanism may actually perform value-informed pricing.

Vulnerability to Disturbance

In theory, the existence of off-equilibrium unreliability cannot completely rule out the existence of competition-informed pricing, because according to conclusion 2 it may still be feasible (though nonviable). Although unlikely, it could be the case that at some earlier development stage of the market, when the quality ambiguity of products was not that low, firms followed the flocking model; however, at a later stage, the quality ambiguity, for whatever reason, becomes low enough for the off-equilibrium unreliability to grow significantly, but, because the firms have been used to the flocking model, they may continue to follow it. Or, it could be the case that the flocking model simply becomes some norm, either tacit or institutionalized, among the firms to coordinate competition and maintain the hierarchy of the market.

However, there is a second kind of dynamic instability, which is more fundamental than off-equilibrium unreliability, inherent in the W(y) mechanism—the vulnerability to disturbance. That is, even if the firms in a market are "blind" to the off-equilibrium unreliability and stick to the W(y) mechanism, the mechanism may still not be viable due to this vulnerability. To better understand the vulnerability to disturbance, recall the metaphor mentioned before: both the peak of a mountain and the bottom of a valley represent some equilibrium states, but a ball at the peak will roll down the slope when disturbed and cannot go back again by itself, while the ball at the bottom of the valley when disturbed can return to the bottom by itself under the force of gravity. Thus, the equilibrium represented by the peak is vulnerable to disturbance, whereas the one represented by the valley bottom is robust to disturbance. It can be shown that the equilibria in some market settings of the W(y) mechanism are the “valley bottom,” while in other settings the equilibia are the “mountain peak.”

Simulation setting one above (with no quality ambiguity) turns out to be a “valley bottom” and thus robust to disturbance. To illustrate this, figure 7 plots the simulation trajectories of the two estimated regression coefficients, B_{0t} and B_{1t} , of the fitted $R_t(y)$ curves across time. The two coefficients oscillate quite stably around their equilibrium values (the horizontal lines), in spite of persisting disturbances. This suggests that the $R_t(y)$ curve fluctuates stably around the equilibrium W(y) curve. Moreover, it can be further shown that if there are only some one-time disturbance at t = 1, that is, all the error terms, ε_{it}’s and δ_{it}’s, are set to zero for $t > 1$, the W(y) flocking mechanism can go back (converge) to equilibrium after some time, which is a more direct piece of evidence for its stability. This is illustrated in figure 8.

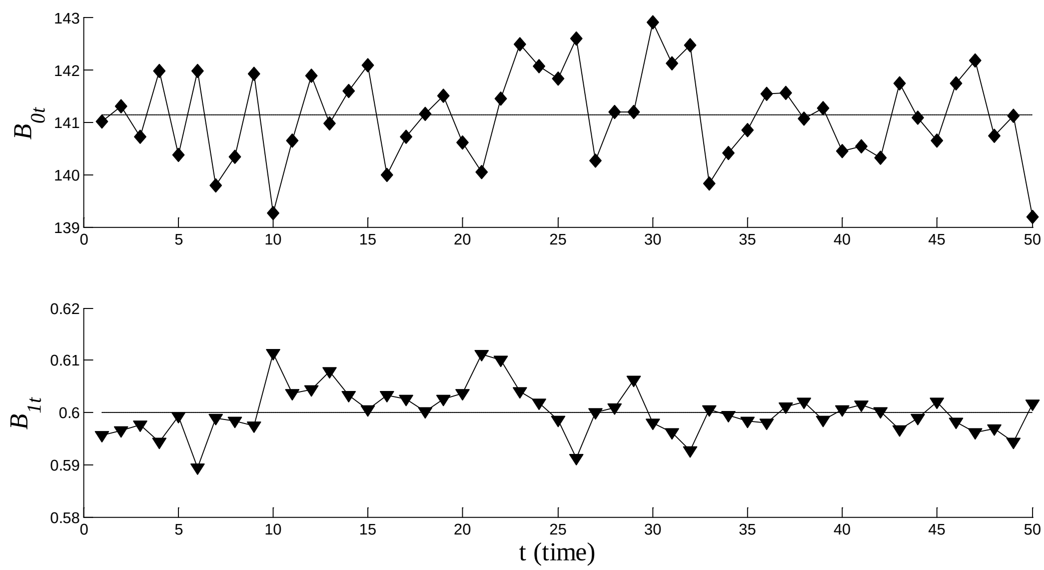

Figure 7: Trajectories of regression coefficients of $R_t(y)$ with persisting disturbances (Setting 1)

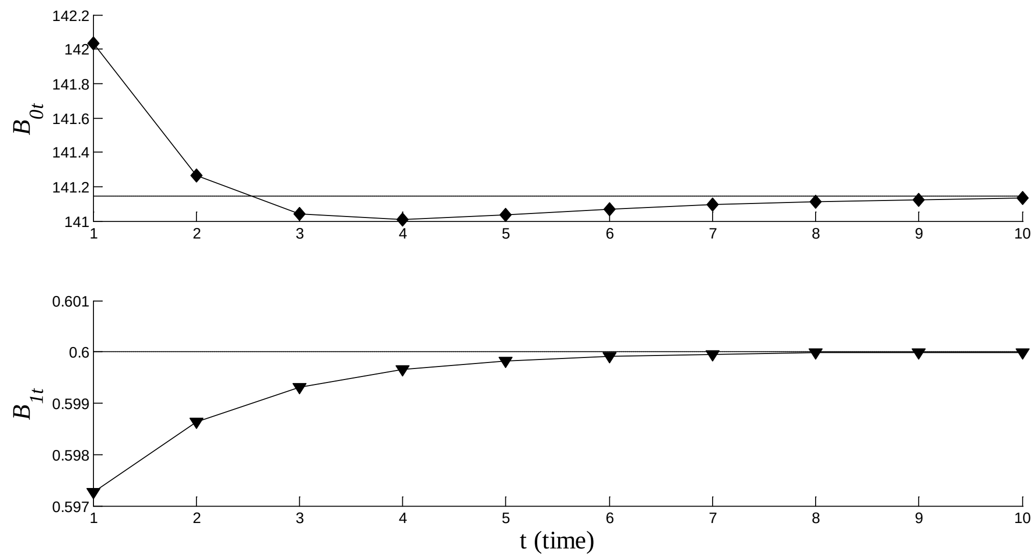

Figure 8: Trajectories of regression coefficients of $R_t(y)$ with one-time disturbances (Setting 1)

However, the two following settings (settings 2 and 3, without quality ambiguity) are the "mountain peak," and thus vulnerable to disturbance. The values of model parameters for these two settings are listed in table 2.[37] Note that both these settings are judged inhabitable for the W(y) mechanism by White. Again, it is assumed that firms totally ignore the problem of off-equilibrium unreliability and stick to the W(y) mechanism.

Table 2: Simulation Settings 2 and 3:

	MARKET PARAMETERS							SIMULATION PARAMETERS		
	a	*b*	*c*	*d*	θ	*r*	*q*	# of Firms (*I*)	Range of Mean Quality.	# of Runs (*T*)
Setting 2	1	1	0.8	-0.5	2	0.7	1	9	[4.5, 12.5]	100
Setting 3	0.8	1	1.2	0.75	2	0.1	1	9	[8, 12]	100

[37] Setting 2 is adapted from the example for "crowded" markets in White (1981a, p. 35), while setting 3 is from the one for "paradox" markets in White (1981a, p. 25).

For setting 2, the simulation trajectories of the two regression coefficients (B_{0t} and B_{1t}), together with their equilibrium values (the horizontal lines), are plotted in figures 9 and 10. Likewise, the simulation results for setting 3 are plotted in figure 11 (the plots are truncated earlier than t=100 in order to see the start of divergence). It turns out that in both settings both persisting and one-time disturbances generate the same kind of trajectories of the regression coefficients, so there is only one figure plotted for both kinds of disturbances.

In setting 2, figure 9 shows that the coefficient B_{0t} quickly falls to zero and B_{1t} turns negative, in which case the $R_t(y)$ curve "collapses" into a horizontal line with zero "height" (see eq. 15) . This suggests that firms would gain zero revenue no matter how large/small their output volumes are. Actually, in this setting, it is equally possible that B_{0t} drastically increase to plus infinity and B_{1t} also increases (see figure 10). In such a case, the $R_t(y)$ curve "explodes," suggesting the revenues of firms could increase unboundedly. Whether the curve collapses or explodes depends on the direction of the initial disturbances, just like the direction of the initial tiny "kick" determines along which side the ball rolls down the hill. In either case, the $R_t(y)$ curves do not make any sense, and thus the W(y) mechanism cannot survive.

In setting 3, figure 11 indicates a third pattern of divergence: the two regression coefficients oscillate around their respective equilibrium values, but the amplitudes of the oscillations increase drastically (the plot is truncated at t = 14, in order to see the start of oscillation). It seems that the disturbances trigger the "resonance" of the system, as if the W(y) mechanism alternates between the two tendencies of "collapse" and "explosion."

Now it becomes clear that settings 2 and 3, though judged inhabitable for the W(y) mechanism by the static model, are subject to the vulnerability to disturbance, and thus cannot sustain the W(y) mechanism. Even if the disturbances are small and one-time, they are sufficient to “kick the ball down the hill”—to cause the W(y) flocking mechanism to collapse, explode, or resonate. It should be noted that, in such cases, the $R_t(y)$ curve does not really collapse to zero, nor really explode or resonate toward infinity. As mentioned before, the current model only addresses the *near-equilibrium* behavior of the W(y) mechanism, but does not capture the dynamics when the mechanism is far from equilibrium. In reality, the market capacity must set limits on its diverging path. But, there is one thing for sure: the W(y) mechanism cannot survive in such settings.

The analytical condition for judging if a specific market setting is vulnerable to disturbance is derived in appendix B. It follows that *many market settings judged inhabitable for the W(y) mechanism by White’s model in all three viable regions* (White 1981b, p. 527, fig. 3) *are not inhabitable due to vulnerability to disturbance*.

Taking into account both kinds of dynamic instability (the off-equilibrium unreliability and vulnerability to disturbance), the W(y) mechanism can hardly survive in any market setting, under the condition of no (or very low) quality ambiguity. However, the mechanism does seem to exist in some, perhaps not too few, real markets (e.g., White 1981b; Uzzi and Lancaster 2004; Chiffoleau and Laporte 2006). A natural speculation is that, in most real markets, the (absolute) quality ambiguity is not that low, so that the W(y) mechanism may be still viable. Then, one has to 1) prove that higher absolute quality ambiguity leads to increased viability of the mechanism, and 2) to find if such a relation holds in the *whole* range of absolute quality ambiguity, or just exists in *some* range of it. These issues are addressed in the next chapter.

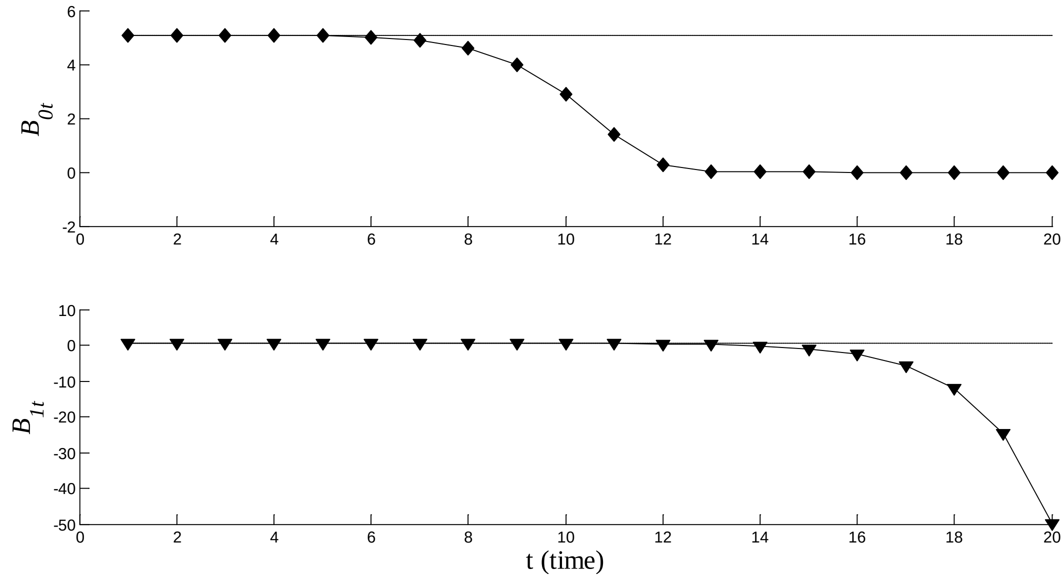

Figure 9: The “collapse” of the $R_t(y)$ curve (Setting 2)

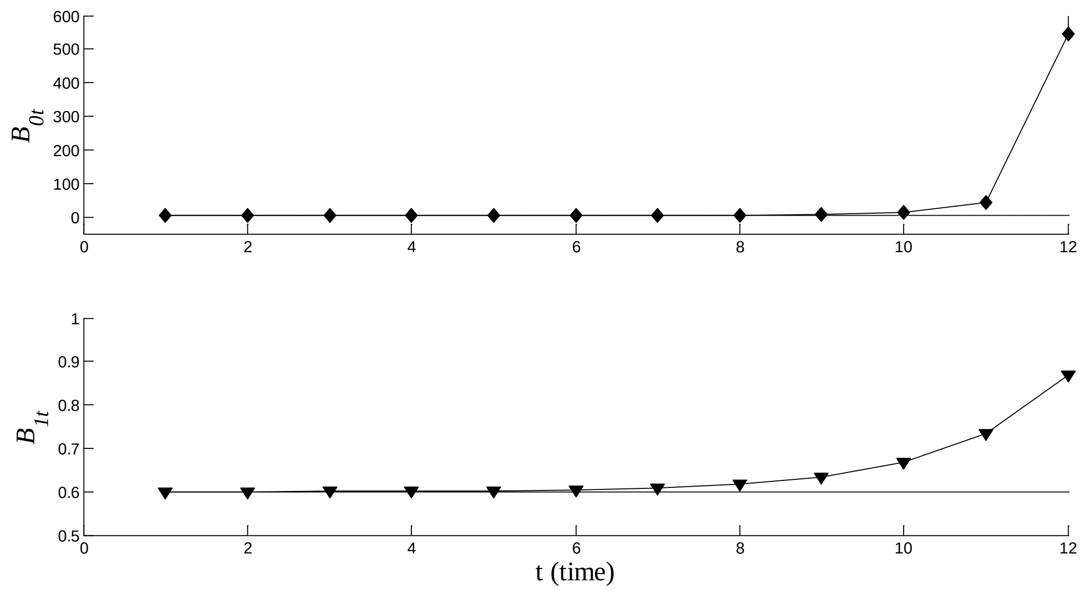

Figure 10: The “Explosion” of the $R_t(y)$ Curve (Setting 2)

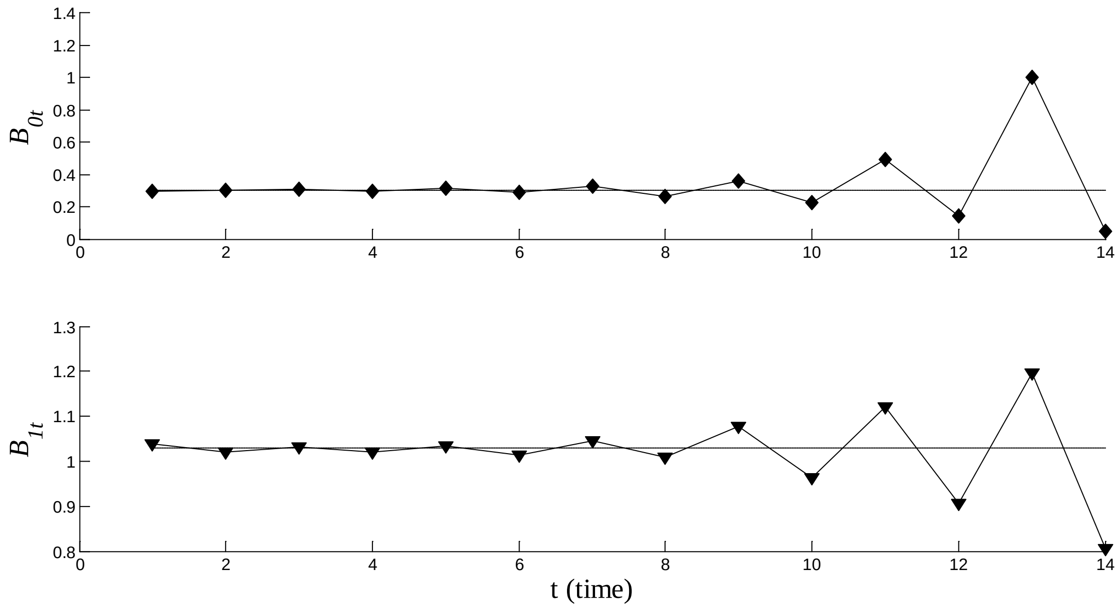

Figure 11: The “Resonance” of the $R_t(y)$ Curve (Setting 3)

Chapter 5 Uncertainty as Stabilizer

In this chapter, the absolute quality ambiguity σ is no longer fixed at zero. Instead, it is increased stepwise. The effects of this increase on the two kinds of dynamic instability of the W(y) flocking mechanism are then examined, and the implications for the viability of the mechanism are discussed, with the assistance of propositions 1 to 4. The three simulation settings above are used again here to illustrate such effects. It should be emphasized that although only three simulation settings are used, the results are representative for other market settings judged inhabitable for the W(y) mechanism by White's model.

Increasing Off-equilibrium Reliability

The problem of off-equilibrium unreliability results from the fact that when the absolute quality ambiguity in the market is low, the predictions provided by the W(y) flocking mechanism are very unreliable and the realized market outcomes deviate systematically from the predicted ones. Now consider the situation in which the absolute quality ambiguity σ is no longer zero, still using setting one as an example. Everything remains the same, except that eleven levels of σ are specified: from 0 to 0.25 with increments of 0.025. The highest level of σ is set such that the "normal range" of each firm's quality exactly reaches the mean quality of the firm(s) with neighboring quality, i.e., $2\sigma = \Delta n$. At each level of absolute quality ambiguity, 100 iterations are run, that is, $T = 100$. Outcomes of interest are the other three market uncertainties: relative quality ambiguity (measured with eq. 8), predictive uncertainty (measured with eq. 3 and 4), and recognitive uncertainty (eq. 1). With the sizes of these uncertainties, the viability of the W(y) mechanism can be evaluated according to the four propositions. All the measured uncertainties at each level of σ are obtained by averaging over time T. The simulation results are plotted in figure 12, with the level of absolute quality ambiguity as the independent variable. Note that the scale of the measures is not very informative, what matters is the tendency.

It is clear from figure 12 that when σ is zero, what endangers the W(y) mechanism is high predictive uncertainty (proposition 2). As the absolute quality ambiguity increases, predictive uncertainty falls, making the survival of the W(y) mechanism possible. What is even more important than the reduced size of predictive uncertainty is the fact that the deviation of the realized market outcomes from the $R_t(y)$ curves becomes less systematic when the absolute quality ambiguity is relatively higher. This is illustrated by figure 13 where the predicted revenue-volume pairs (the X's) and the realized ones (the dots) of three firms (with respective mean qualities n_1, n_2, and n_3) are plotted along with the equilibrium W(y) curve; the corresponding σ is 0.225. Compared with figure 6 (with no quality ambiguity), in which the realized outcomes (the dots) reveal a clear pattern deviating from the W(y) curve, those in figure 13 seem more evenly and randomly scattered around the W(y) curve (and also the $R_t(y)$ curves, which are not plotted). This suggests that in this setting the $R_t(y)$ curves can provide seemingly more credible predictions, for all firms in the market, of the sales revenues corresponding to various volumes. Thus, for each run, the firms have good reasons to accept the fitted $R_t(y)$ curve as their revenue curve. This result also holds in all other possible market parameter settings.

The reason for reduced predictive uncertainty and less systematic deviation is that as absolute quality ambiguity increases, consumers become less critical or “picky” about product quality, so the sharp valuation curves expand to “fuzzy” valuation bands (see figure 5). As a result, consumers are more tolerant of the deviation of the firms’ offers, and thus the firms’ (randomly) deviated offers are more likely to be accepted. Metaphorically, the role of the absolute quality ambiguity in the W(y) flocking mechanism is akin to that of lubricant—it makes the originally rigid, brittle, and friction-fraught system more flexible, robust, and smooth.

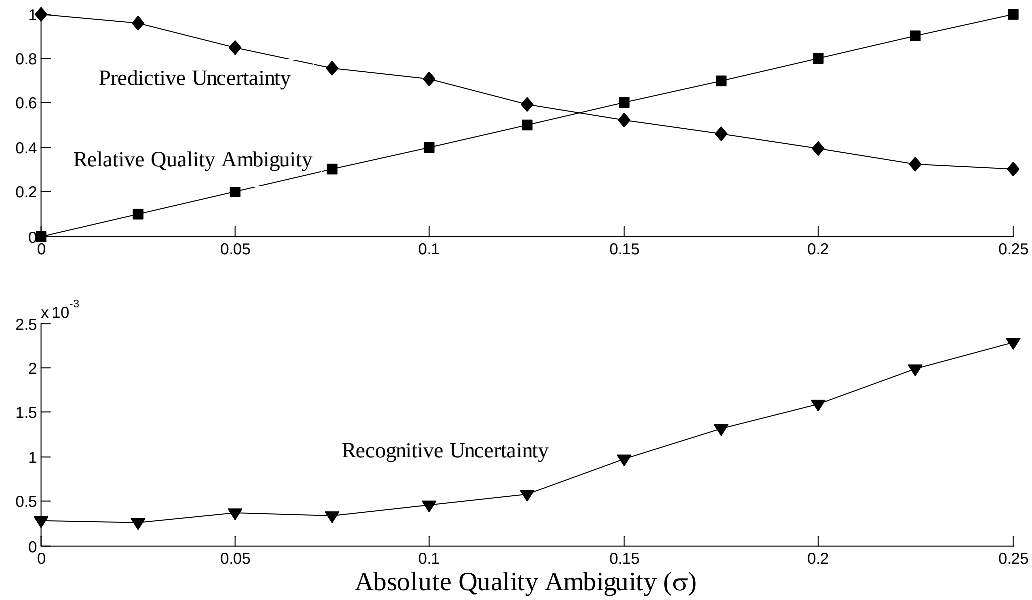

Figure 12: The Predictive, Recognitive Uncertainties and Relative Quality Ambiguity against Absolute Quality Ambiguity (Setting 1).

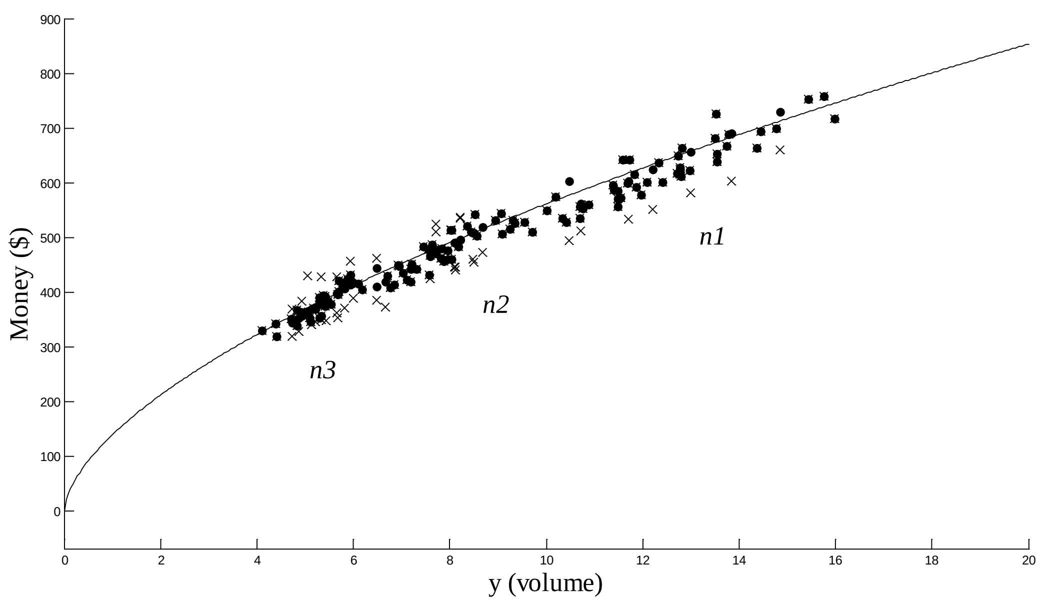

Figure 13: The Realized (the dots) and Predicted (the X's) Revenues and Volumes (Setting 1; σ = 0.225), Along with the W(y) Curve in Equilibrium.

However, reduced predictive uncertainty generates greater relative quality ambiguity (assuming that Δn, the distances between the mean qualities of firms with neighboring quality distributions, are constant),[38] and increases recognitive uncertainty (see figure 12).[39] Thus, if the absolute quality ambiguity is too high, the resulting relative quality ambiguity and recognitive uncertainty would be too high for the W(y) mechanism to survive (propositions 1 and 4). This leads to the following conclusion:

> *Conclusion 3*: the W(y) mechanism (i.e. competition-informed pricing) is only viable in some middle range of absolute quality ambiguity. If the absolute quality ambiguity is either too low or too high, the mechanism would be nonviable.

Strengthening Robustness to Disturbance

Having illustrated the role of absolute quality ambiguity in increasing the off-equilibrium reliability of the W(y) flocking mechanism, it is now time to examine its effects on vulnerability to disturbance. Simulation settings 2 and 3 are again used as examples. Eleven levels of σ are specified for each setting in the same manner as in setting 1. However, the outcome of interest now becomes the timing of the start of divergence—"collapse," "explosion," or "resonance"—of the fitted $R_t(y)$ curves at each level of σ. Such timing can be observed from the simulation

---

[38] In another simulation not shown here, as absolute quality ambiguity σ is increased stepwise, the quality distance Δn is also increased accordingly, such that relative quality ambiguity is kept constant. However, this does not change the directions of the trajectories of predictive uncertainty and recognitive uncertainty in figure 12. Thus, conclusion 3 still holds.

[39] Note that the recognitive uncertainty measured here tends to be under-estimated. Spoiled by the increased consumer tolerance, firms are emboldened to make more deviating offers, which would increase the variation in market outcomes. This possibility is not considered here, since the firm's tendency to deviate is assumed constant, as modeled by the standard deviations of the error terms ε_{it}'s and δ_{it}'s in eqs. 19 and 20.

trajectories of the two estimated regression coefficients, B_{0t} and B_{1t}, of the $R_t(y)$ curves.

The simulations reveal a general tendency: the larger the σ, the later the divergence starts. By plotting the time trajectories of the logarithm of the estimated coefficient B_{0t}, figures 14 and 15 show, for settings 2 and 3 respectively, the different timings of divergence at three levels of σ. Since the divergences of the two regression coefficients are almost synchronized, only one coefficient is plotted. The two figures demonstrate the general tendency. Increased absolute quality ambiguity tends to delay the divergence of the W(y) mechanism; with σ sufficiently large, the mechanism becomes rather stable.

Metaphorically, the reason for the increased robustness to disturbances is that the existence of absolute quality ambiguity "cuts off" the crest of the mountain and makes the mountain a mesa, and the tableland formed at the top represents some local semi-stable equilibrium. The equilibrium state is only semi-stable because after experiencing some one-time disturbance, the ball on the tableland would not return to its original place, nor would it keep rolling away down the hill; rather, it would stay at some location near the original place. The equilibrium state is only local because the semi-stability holds only within the area of the tableland: if the disturbances are big enough to "kick" the ball off the edge, the ball would keep rolling away.

If the disturbances are small enough and their directions are largely random, their effects on the ball would cancel out each other, and the overall effect would be that the ball would always stay near the original place. The greater the absolute quality ambiguity, the larger the portion of the mountain crest removed, the larger the area of the tableland, and thus the greater the ability to resist occasionally extra-large disturbances. This is why increased absolute quality ambiguity can strengthen the W(y) mechanism's robustness to disturbances, and make it feasible in those settings otherwise uninhabitable (such as settings 2 and 3). However, this is achieved at the expense of higher relative quality ambiguity[40] and recognitive uncertainty. Therefore, although *some* level of absolute quality ambiguity is necessary to the stability of the W(y) flocking mechanism, too much of absolute quality ambiguity would undermine and even nullify such benefit, as the result of increased relative quality ambiguity and recognitive uncertainty. This leads to the same conclusion as conclusion 3. See appendix B for a more technical explanation of the rationale for this phenomenon.

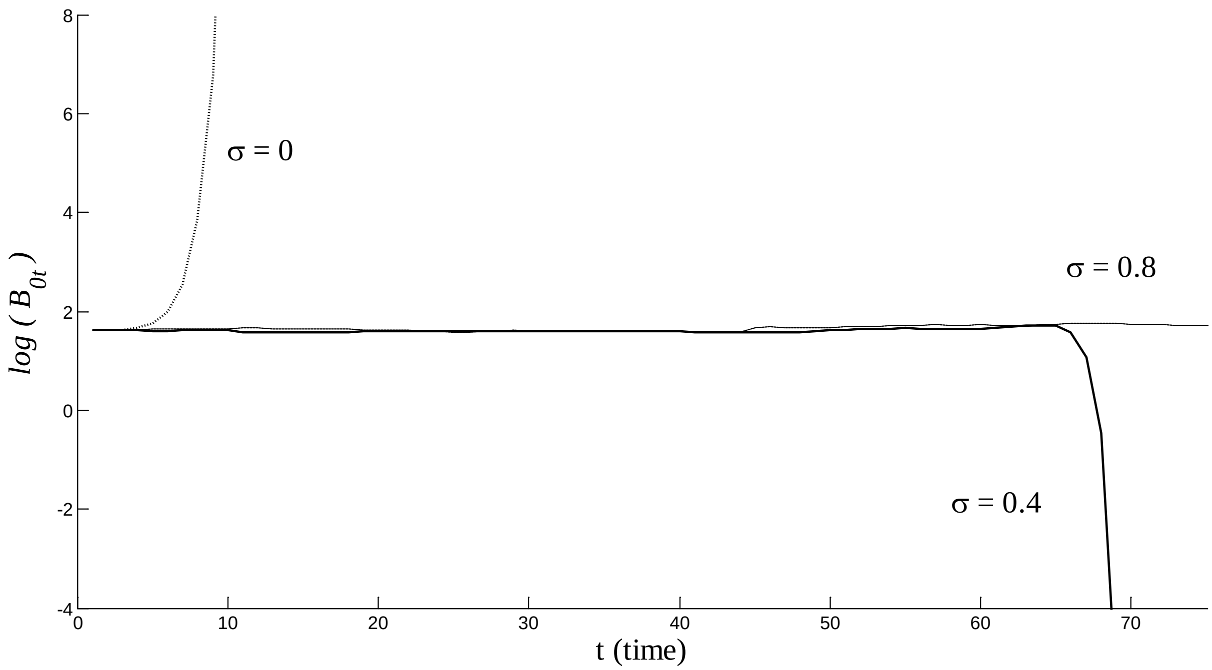

Figure 14: The Timing of Divergence (Setting 2)

(Notes: dotted line: $\sigma = 0$; solid line: $\sigma = 0.4$; dashed horizontal line: $\sigma = 0.8$)

[40] In another simulation not shown here, as absolute quality ambiguity σ is increased stepwise, the quality distance Δn is also increased accordingly, such that relative quality ambiguity is kept constant. However, this does not change the tendency shown in figure 14. Thus, the conclusion remains the same.

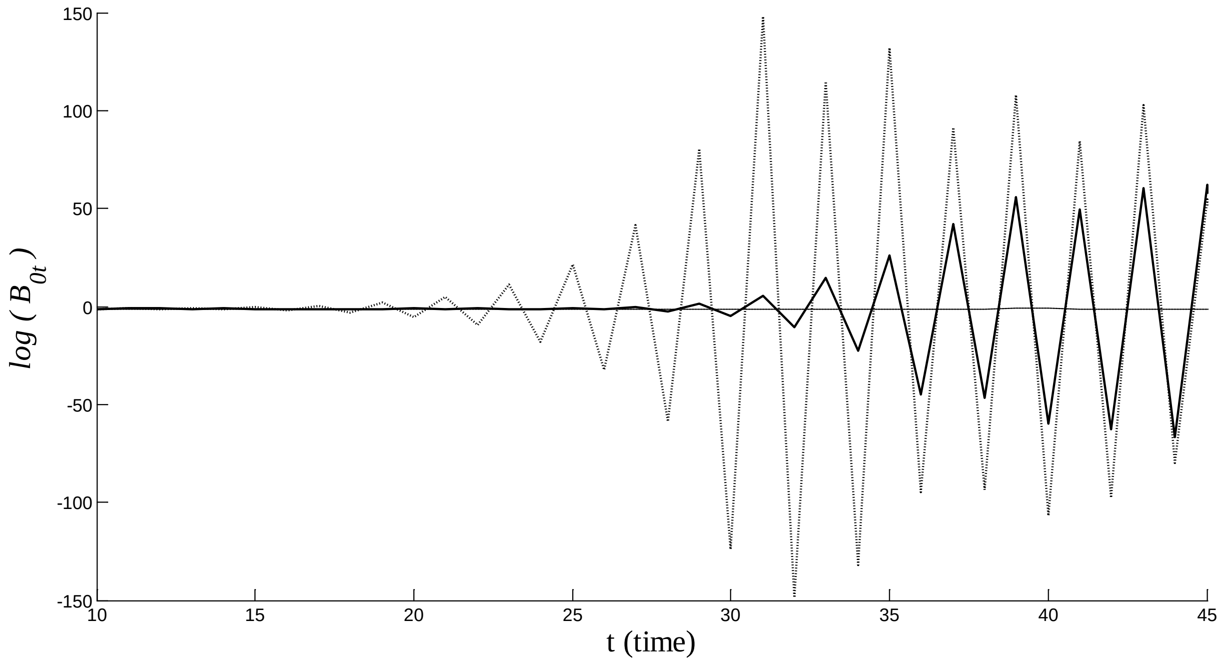

Figure 15: The Timing of Divergence (Setting 3)

(Notes: dotted line: σ = 0; solid line: σ = 0.4; dashed horizontal line: σ =0.8)

Discussion

In this chapter, the viability conditions for different pricing practices—the W(y) mechanism (or competition-informed pricing), value-informed, and cost informed pricing—are first summarized according to propositions 1 to 4, and conclusions 1 to 3. The current theory is then used to explain the distribution of different pricing practices in the case of the Burgundy wine market. Some evidence supporting the current theory in existing studies, its immediate theoretical and practical implications, and a future research agenda are also discussed.

To facilitate summary, all market settings discussed in this dissertation are placed on a plane in figure 16 spanned by two independent variables: the absolute quality ambiguity σ and the distance between two neighboring mean qualities Δn. The two dotted horizontal lines roughly divide the plane into three areas. From bottom to top, they respectively represent low (L), medium (M), and high (H) absolute quality ambiguity. The two dashed rays from the origin also roughly divide the plane into three areas: from left to right, they respectively represent high, medium, and low relative quality ambiguity (see eq. 8). Thus, the four lines together divide the plane into nine regions, each of which corresponds to a unique combination of the levels of absolute and relative quality ambiguity. These combinations are denoted by two letters, the first referring to the level of absolute quality ambiguity, and the second to the level of relative quality ambiguity. For example, the region marked with "LH" has low absolute and high relative quality ambiguity; the region with "HL" has high absolute and low relative quality ambiguity. Now the viability of different pricing practices can be summarized with the help of this topology of quality ambiguities.

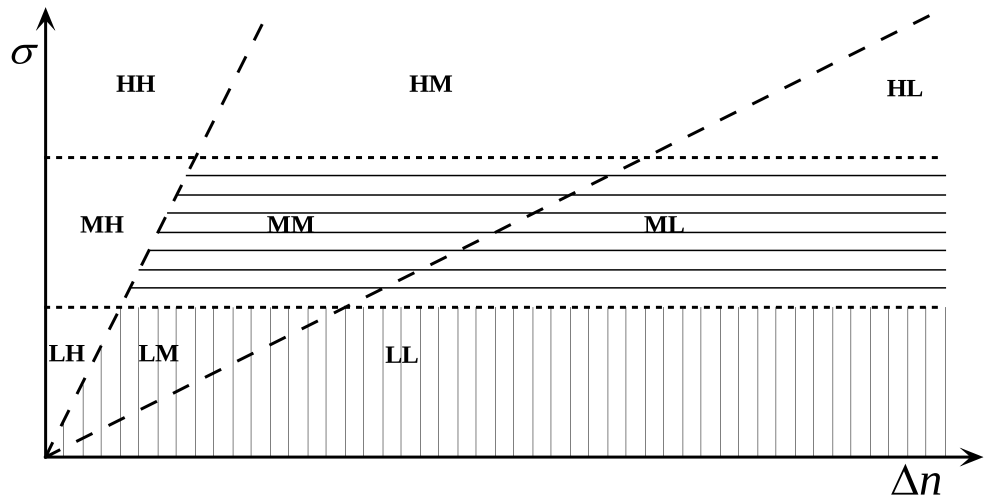

Figure 16: The Topology of Quality Ambiguities and the Viability of Pricing Practices (Notes: horizontally shaded area: competition-informed pricing; vertically shaded: value-informed pricing; no shade: cost-informed pricing)

In the three regions at the top of the plane (HH, HM, HL) having high absolute quality ambiguity, both the W(y) mechanism and value-informed pricing are nonviable. Value-informed pricing is nonviable because high absolute quality ambiguity suggests that consumers have no clear valuation of the products in the first place, let alone the firm's possibility of revealing it (proposition 3). The W(y) mechanism is nonviable because high absolute quality ambiguity gives rise to high recognitive uncertainty (figure 12), which compromises the firm's ability to fit the $R_t(y)$ curves or its confidence in it (proposition 1, conclusion 3), and for region HH, high relative quality ambiguity would also make the mechanism nonviable (proposition 4). For the two regions on the left (MH, LH), the W(y) mechanism and value-informed pricing are not viable either, since the high relative quality ambiguity undermines product differentiation, which is the very basis of the two pricing mechanism/practices (proposition 4). In these five regions, only cost-informed pricing is viable, because its focus on the internal cost structure of the firm, to a large extent, guards the firm from both quality ambiguities.

For the remaining four regions, the W(y) mechanism can only occupy the two regions (MM, ML) with medium level of absolute quality ambiguity (conclusion 3), but cannot survive in the other two (LM, LL) with low absolute quality ambiguity (conclusion 2). Low absolute quality ambiguity endangers the flocking model of competition-informed pricing with two dynamic instabilities—off-equilibrium unreliability and vulnerability to disturbance.

Value-informed pricing is only viable in the two regions (LM, LL) with low absolute quality ambiguity (conclusion 1). The survival of value-informed pricing relies heavily on the existence of rather clear valuations of products by consumers, which, in turn, rely on the relatively unambiguous evaluation of product quality. This concludes the summary of the viability conditions for different pricing practices.

It should be emphasized that this categorization of the "continuous distributions" of quality ambiguities is oversimplified. In reality, the shapes of the "territories" of these pricing mechanism/practices would be "distorted," and their boundaries would be blurred. The territories, to some extent, would also overlap with each other. These complications in reality are also reflected in the fact that for each firm, the adopted pricing practice tends to be, more or less, a hybrid of all three. However, these practical issues are left for future empirical research; for the purpose of this dissertation, it suffices to provide a somewhat idealized theoretical map, which serves as the baseline against which various deviations and distortions can be further studied. Even in its current crude form, this map can still offer important insights into the empirical distribution of pricing practices.

For example, consider again the case of the Burgundy wine market. According to Chiffoleau and Laporte (2006), the producers who adopt value-informed pricing are mostly those owning the most prestigious appellation (highest quality/status). Producers who use cost-informed pricing (and price takers) are mostly concentrated at the lowest end of the quality/status spectrum, and those who practice competition-informed pricing (the W(y) mechanism) are often associated with middle level quality/status. A possible explanation for this pattern is that the absolute and relative quality ambiguities associated with the producers' wines are correlated with the mean qualities of the products: the higher the mean quality, the lower the absolute and relative quality ambiguities.

This relationship is quite plausible, because a firm with high quality/status usually has invested a lot in advertising, networking, and cultivation of clientele, as confirmed by Chiffoleau and Laporte. Thus, the firm has fostered the formation of relatively consistent quality evaluation of its product among consumers (low absolute quality ambiguity), and has also sufficiently differentiated the image of its product from those of its direct competitors (low relative quality ambiguity).[41] In contrast, those firms located at the lowest end of the quality spectrum may have no sufficient means and resources to do this (also confirmed by Chiffoleau and Laporte). Even if they had, they would be still reluctant to do so, because the gain, compared with the cost, may be minimal, given the low mean quality. Therefore, in the eyes of consumers, although they may all have low mean qualities, consumers cannot tell exactly how different they are from each other in terms of quality—they, in the eyes of consumers, even may not be worth careful evaluation, given the low utility to do so. The result is high absolute and relative quality ambiguities in this segment. Following the same logic, firms in the middle range of the quality spectrum should have medium absolute and relative quality ambiguities.

---

[41] That is, it is not the high quality/status *per se* that enables the firm to perform value-informed pricing (as commonsense or intuition may tell us). Rather, it is the low absolute and relative quality ambiguities, usually associated with high mean quality, that allow the firm to do so.

According to the map in figure 16, the whole Burgundy wine market would, thus, split into at least three sub-markets, with the one at the high end practicing value-informed pricing, the one of middle quality practicing competition-informed pricing (the W(y) mechanism), and the one at the low end practicing cost-informed pricing, or simply becoming price takers (as in perfectly competitive theory without product differentiation). This general picture is quite consistent with that provided by Chiffoleau and Laporte. Although they also purport to explain the distribution of pricing practices using appellation and sales structures as explanatory variables, the current theory offers a deeper and more comprehensive explanation for the phenomenon—the roles and effects of appellation and sales structures may themselves be some function of, or mediated by, the distributions of market uncertainties.

The phenomenon of the Burgundy wine market is by no means unique. On the contrary, it may be quite common in empirical markets. Marketing researchers have long found a positive association between the successfulness of firms and the implementation of value-informed pricing (e.g. Cressman 2009; Dutta *et al.* 2003; Hinterhuber 2008; Ingenbleek 2007; Ingenbleek *et al*. 2003). They tend to interpret this association as evidence for supporting the argument that value-informed pricing leads to the success and high performance of firms; thus every firm, in principle, should adopt it. However, the current theory suggests the possibility of reversing the causal direction between the two: because the firms had become successful by reducing both the absolute and relative quality ambiguities of their products, they created the market conditions for implementing value-informed pricing. That is, value-informed pricing may be, to a large extent, a by-product of success, rather than a cause of it.

Actually, Ingenbleek (2007) and Ingenbleek *et al*. (2003) have found empirical evidence that the effects of value-informed pricing are conditioned on the level of market uncertainty and intensity of competition: high market uncertainty and intensive market competition tend to undermine the "positive effects" of value-informed pricing on firms' performance. In the language of the current theory, "high market uncertainty" may be translated into "high absolute quality ambiguity," and "intensive market competition" may be interpreted as "high relative quality ambiguity." Thus, the results can be re-explained as: high absolute and relative quality ambiguities compromise the viability of value-informed pricing. Unfortunately, Ingenbleek *et al.* fail to consider the possible reversal of the causality, continuing to claim a "universal positive effect" of value-informed pricing, and thus they advocate its universal superiority over other pricing-practices. In contrast, a practical implication of the current theory is that firms should choose the pricing practices most suitable for the levels of absolute and relative quality ambiguities associated with its product. If a firm indeed wants to implement value-informed pricing, it has to first reduce the two quality ambiguities of its product to a rather low level. Then, the practical issue becomes one of weighing up the gains and losses of doing this.

To further test the theory, a series of refutable hypotheses concerning the relationship between the prevalence of pricing practices and levels of different uncertainties can be readily derived from figure 16. The next step is to empirically measure the absolute and relative quality ambiguities of some sample of firms in some markets, and then to assess the statistical relation between these uncertainties and the prevalence of different pricing practices. The pricing orientation of firms can be obtained by survey-based studies (Ingenbleek *et al.* 2003), and the quality ambiguities of their products, though hard to measure due to their uncertain nature, may be indirectly captured by measuring the σ's and Δn's of the distributions of customer ratings, for example, in the "customer reviews" sections of shopping websites. This equally challenging task, however, is left for future research.

The current study has close connections to the sociological theory of status formation based on the conceptual distinction between (true) quality and status (Podolny 1993, 1994, 2001; Gould 2002; Lynn et al. 2009), though the current study emphasizes quality ambiguity as some irreducible uncertainty (thus questions the existence of “true quality”) and, for practical purposes, focuses on some generalized “quality” that subsumes status as one of its many possible dimensions. In this dissertation, the quality distributions of all firms are regarded as given and static, while the dynamic formation of these distributions is largely ignored. However, the latter is the very issue addressed by the status-based model (though the quality dispersion of a single product is not its focus). Thus, integrating the two modeling approaches may be a fruitful direction for future research, which may better explain how the distributions of quality ambiguities in a specific market (such as the Burgundy wine market) take shape.

Conclusion

Given the central position of the sociology of markets in economic sociology, the lack of theoretical and empirical attention to the price phenomenon is recognized as a “profound shortcoming” (Beckert 2011). Further, among the three major aspects of the price phenomenon—qualification/valuation of goods, price mechanisms at the market and inter-firm level, and pricing practices at the organizational and intra-firm level—pricing practices are the least studied in sociology. However, it is by no means the least important, since the organizational device of pricing practices adopted by firms to set prices, together with price mechanisms at the market level, constitute two intertwined channels through which the values of goods are translated into prices. Without theoretically engaging pricing practices, a crucial link is missing in economic sociology that connects the values/valuation of goods, which has recently received much sociological attention, to the core issue of the price phenomenon—price formation (Beckert 2011; Uzzi and Lancaster 2004).

This study addresses three interrelated questions. Why may different firms, even in the same market, use different pricing practices—value-informed, competition-informed, or cost-informed pricing—to make pricing decisions? Among the three pricing practices, is there a universally superior one, such as competition-informed pricing implied by Harrison White’s market theory (White 1981a, b, 2002) or value-informed pricing promoted by marketing scholars? What are the market conditions for different pricing practices to survive?

To answer these questions, this study builds a dynamic price flocking model, which cuts across all three aspects of the price phenomenon, to explore why and how the viability of different pricing practices depends on the distributions of a variety of market uncertainties.

Departing from Harrison White's static W(y) market model (White 1981a, 1981b, 2002), which corresponds to competition-informed pricing, this study revises and extends it by introducing into the model the *inter-dynamics* among the W(y) mechanism and various market uncertainties. The theory implies that each kind of pricing practice is only viable under certain combinations of levels of different market uncertainties. Thus, this study offers a theoretical map for the relationship between the topology of market uncertainties and the viability of pricing practices. The practical implication is: contrary to what White's theory or marketing scholars suggest, there is no universally superior pricing practice; the best pricing practice for a firm is contingent on the specific levels of uncertainties associated with its product. The theory is then used to explain the distribution of pricing practices in the case of the Burgundy wine market.

The current study also contributes to the sociological research on uncertainty. The existing literature views uncertainty as either "undesirable" or "desirable." The "undesirable" view of uncertainty argues that the existence of uncertainties undermines social actors' ability to make (the "right") decisions and coordinate with each other, and thus constantly threats to disrupt social order (or hinder its emergence) and lead to chaos. To impose (or sustain) social order, certain social mechanisms or structures must be invoked to reduce or even eliminate uncertainties. In contrast, the "desirable" view of uncertainty sees uncertainties as some "assets" that should be capitalized rather than "liabilities" that should be gotten rid of, because the ambiguous situations generated by uncertainties suggest opportunities for social actors to break free from the over-determined constraints imposed by the existing social order and to gain profits and advantages (Knight 1921; Stark 2009). Despite the opposition at the surface, the two views share the same underlying logic—uncertainty is disruptive to existing social order.

However, the current study challenges this "commonsense:" the existence of some uncertainty may well enhance the stability of social order. The role of uncertainty is not merely as some logical precondition for invoking certain social mechanisms/structures to manage it—just as in the statement "because uncertainty *A* exists, mechanism/structure *B* is invoked to deal with it." Rather, uncertainty may be indispensible and internal to the normal functioning of social mechanisms, as is illustrated by the case of the W(y) flocking mechanism. The absolute quality ambiguity, conceptualized as some tolerance interval shared by market actors, is akin to some lubricant: it makes the otherwise rigid, brittle, and friction-fraught social order—the "interface discipline" (White 2002)—imposed by the W(y) mechanism more smooth, robust, and error-tolerant.

Quality ambiguity/uncertainty is an important kind of uncertainty that has received a great deal of theoretical attention from both sociologists and economists. The problem of quality ambiguity is usually formulated as one of asymmetric information. That is, it is assumed that there is some "true" quality associated with a certain product, and the only problem is the unavailability of reliable information revealing this "true" quality to the buyer/consumer. After the buyer purchases and uses this product for a while, the "true" quality is revealed. However, such a formulation makes sense only when the standards and procedures for evaluating quality are quite clear and consistent among both consumers and producers. In reality, as is implied by the recent scholarship of marketing research and the sociology of performativity (e.g., Finch 2010; Kjellberg 2007; Kjellberg and Helgesson 2006; Callon *et al*. 2002; Callon and Muniesa 2005), there are ambiguities and discrepancies intrinsic in the standards, procedures, and processes both producers and consumers use to evaluate and compare qualities, individually or collectively. Thus, strictly speaking, there is no "true" quality; rather, there is only mean quality and distribution of quality surrounding the mean. The question addressed here is not how social mechanisms reduce quality ambiguity and impose market order, but rather the role of the persisting quality ambiguity, as some non-negligible irreducible uncertainty faced by both sides of transaction, in the functioning of the social mechanisms maintaining market order.

As the relationship between uncertainty and social order has been a unifying theme in economic sociology (and sociology in general), this dissertation may open up a new line of inquiry that has important implications for a wide range of research. Existing studies have given detailed accounts of a variety of social constructs that manage uncertainties, such as status, networks, culture and institution; some studies further demonstrate that different mechanisms are invoked in response to different kinds or levels of uncertainties (e.g., Beckman, Haunschild, and Phillips 2004; DiMaggio and Louch 1998; Peterson 1997; Podolny 2001). However, these studies more or less follow a common logic: "because uncertainty *A* (or *B*) exists, mechanism *C* (or *D*) is invoked to deal with it." This, as illustrated herein, does not give adequate consideration to the inter-dynamics between uncertainties and social mechanisms. Mechanism *A* may indeed reduce uncertainty *C*, but at the same time may increase uncertainties *E* and *F*, which may in turn affect the functioning of mechanism *A*. Moreover, the changes in these uncertainties may not be evenly distributed among social actors. Then how do these complications feedback to the social mechanism at work and the evolving market order?

For example, in the status-based theory, some status hierarchy may arise in a market to reduce quality ambiguity through a mechanism in which firms tend to establish ties with those of similar status (Podolny 1994). This clustering process based on status homophily may reduce absolute quality ambiguity in the whole market, as one can recognize a high (or low) quality firm by the statuses of its associates. However, this process may increase relative quality ambiguity among firms within a status cluster, because the clustering makes the perceived qualities of these firms closer to each other and thus decreases the quality differentiation among them. A result might be intensified competition among the firms within each status cluster. Moreover, these changes in absolute and relative quality ambiguities may not be evenly distributed among firms and status clusters. Then, how would these diverging changes in different uncertainties affect the status actions of firms at the micro-level and the evolving shape of the status hierarchy at the macro-level (see also Sauder, Lynn, and Podolny 2012)? Would the status hierarchy finally settle down in some equilibrium, or the actors introduce some other mechanism(s) to either counteract the effects of the changing uncertainties or even replace the status-based mechanism? What are the conditions for triggering each of these different courses?

Similar considerations may well apply to other traditions of sociological research on uncertainty, suggesting promising avenues for future research. A general implication is: uncertainties, and the inter-dynamics among them, should be treated as an endogenous and integral part of the social mechanism at issue, rather than some amorphous "other" external to it. This study, through a fine-grained analysis of different market uncertainties and their inter-dynamics with the pricing practices of firms, provides an example of this approach.

Bibliography

Akerlof, Geoge A. 1970. “The Market for ‘Lemons’: Quality Uncertainty and the Market Mechanism.” *The Quarterly journal of economics* 84:488 - 500.

Alchian, A. A. 1950. “Uncertainty, Evolution and Economic Theory.” *The Journal of Political Economy* 58:211-221.

Ania, Ana B. 2008. “Evolutionary stability and Nash Equilibrium in Finite Populations, with an Application to Price Competition.” *Journal of Economic Behavior & Organization* 65:472-488.

Aspers, Patrik. 2010. *Orderly Fashion: A Sociology of Markets. Princeton*. N.J.: Princeton University Press.

Aspers, Patrik, and Jens Beckert. 2012. “Value in Markets.” Pp. 3-38 in *The Worth of Goods: Valuation and Pricing in the Economy*, edited by Patrik Aspers and Jens Beckert. Oxford, U.K.: Oxford University Press.

Baker, Wayne E. 1984. “The Social Structure of a National Securities Market.” *The American Journal of Sociology* 89:775-811.

Becker, G. S. 1962. “Irrational Behavior and Economic Theory.” *The Journal of Political Economy* 70:1-13.

Beckert, Jens. 1996. “What is Sociological about Economic Sociology? Uncertainty and the Embeddedness of Economic Action.” *Theory and Society* 25:803-40.

——. 2011. “State of the Art: Where Do Prices Come from? Sociological Approaches to Price Formation.” *Socio-Economic Review* 11:1-30.

Beckman, Christine M., Pamela R. Haunschild, and Damon J. Phillips. 2004. “Friends or

Strangers? Firm-Specific Uncertainty, Market Uncertainty, and Network Partner Selection." *Organization Science* 15: 259-275.

Benjamin, Beth A., and Joel M. Podolny. 1999. "Status, Quality, and Social Order in the California Wine Industry, 1981-1991." *Administrative Science Quarterly* 44:563-89.

Callon, Michel, Cécile Méadel, and Vololona Rabeharisoa. 2002. "The Economy of Qualities." *Economy and Society* 31: 194-217.

Callon, Michel, and Fabian Muniesa. 2005. "Peripheral Vision: Economic Markets as Calculative Collective Devices." *Organizational Studies* 26: 1229-1250.

Carruthers, Bruce G., and Brian Uzzi. 2000. "Economic Sociology in the New Millennium." *Contemporary Sociology* 29:486-94.

Chamberlin, Edwin H. 1962. *The Theory of Monopolistic Competition*, 8th ed. Cambridge: Harvard University Press.

Chiffoleau, Yuna and Catherine Laporte. 2006. "Price Formation: The Case of the Burgundy Wine Market." *Revue française de sociologie* (Supplement: An Annual English Selection) 47:157-182.

Cochoy, Franck. 1998. "Another Discipline for the Market Economy: Marketing as a Performative Knowledge and Know-how for Capitalism." Pp.194–221 in *The Laws of the Markets*, edited by Michel. Callon. Oxford: Blackwell.

Cressman, George E. 2009. "Why Pricing Strategies Fail?" *The Journal of Professional Pricing* 2nd Quarter: 18-22.

DiMaggio, Paul, and Hugh Louch. 1998. "Socially Embedded Consumer Transactions: For What Kinds of Purchases Do People Most Often use Networks?" *American Sociological Review* 63:619-37.

DiMaggio, Paul, and Walter Powell. 1983. "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields." *Theory and Society* 25:803-840.

Dubuisson-Quellier, Sophie. 2012. "Where Do New Markets Come from?" Paper presented at the Max Planck Institute for the Study of Societies. http://www.mpifg.de/projects/new_markets/paper_library_en.asp.

Durkheim, Émile. 1947. *On the Division of Labor in Society*. New York, N.Y.: The Free Press.

Dutta, Shantanu, Mark J. Zbaracki, Mark Bergen. 2003. "Pricing Process as a Capability: A Resource-Based Perspective." *Strategic Management Journal* 24:615-630.

Favereau, Olivier, Olivier Biencourt, and Francois Eymard-Duvernay. 2002. "Where Do Markets Come From?—From (Quality) Conventions!" Pp.213-52 in *Conventions and Structures in Economic Organization: Markets, Hierarchies, and Networks*, edited by Olivier Favereau and Emmanuel Lazega. Cheltenham, UK: Edward Elgar.

Finch, John. 2007. "Economic Sociology as a Strange Other to Both Sociology and Economics." *History of the Human Sciences*. 20: 123-40.

Finch, John and Susi Geiger. 2010. "Positioning and relating: Market boundaries and the slippery identity of the marketing object." *Marketing Theory* 10: 237-51.

Fligstein, Neil, and Luke Dauter. 2007. "The Sociology of Markets." *Annual Review of Sociology* 33:105-28.

Fourcade, Marion. 2007. "Theories of Markets and Theories of Society." *American Behavioral Scientist* 50:1015-34.

——. 2011. "Cents and Sensibility: Economic Valuation and the Nature of 'Nature'." *American Journal of Sociology* 116:1721-77.

Friedman, Milton. 1953. "The Methodology of Positive Economics." In M. Friedman (Ed.), *Essays in Positive Economics*: pp.3-43. Chicago: University of Chicago Press.

Gould, Roger V. 2002. “The Origins of Status Hierarchies: A Formal Theory and Empirical Test.” *The American Journal of Sociology*. 107:1143-1178.

Granovetter, Mark. 1985. “Economic Action and Social Structure: The Problem of Embeddedness.” *The American Journal of Sociology* 91:481-510.

Hall, R.L. and C.J. Hitch. 1939. “Price theory and Business Behavior.” *Oxford Economic Papers* 2: 12-45.

Hayek, Friedrich V. 1945. “The Use of Knowledge in Society.” *American Economic Review* 35(4): 519-30.

Hinterhuber, Andreas. 2008. “Consumer Value-based Pricing Strategies: Why Companies Resist?” *Journal of Business Strategy* 29: 41-50.

Huault, Isabelle and Hélène Rainelli-Le Montagner. 2009. “Market Shaping as an Answer to Ambiguities: The Case of Credit Derivatives.” *Organization Studies* 30: 549-75.

Ingenbleek, Paul. 2007. “Value-informed pricing in its organizational context: literature review, conceptual framework, and directions for future research.” *Journal of Product & Brand Management* 16: 441-58.

Ingenbleek, Paul, Marion Debruyne, Ruud T. Frambach, and Theo M. M. Verhallen. 2003. “Successful New Product Pricing Practices: A Contingency Approach.” *Marketing Letters* 14: 289-305.

Kirzner, Israel. 1973. *Competition and Entrepreneurship*. Chicago: University of Chicago Press.

Kjellberg, Hans, and Claes-Fredrik Helgesson. 2006. “Multiple Versions of Markets: Multiplicity and Performativity in Market Practice.” *Industrial Marketing Management* 35: 839-55.

Knight, F. H. 1921. *Risk, Uncertainty, and Profit* (1st ed.). Boston: Hart, Schaffner & Marx;

Houghton Mifflin.

Leifer, Eric M. 1985. “Markets as Mechanisms: Using a role structure.” *Social Forces* 64:442-72.

Lynn, Freda B., Joel M. Podolny, and Lin Tao. 2009. “A Sociological (De)Construction of the Relationship between Status and Quality.” *The American Journal of Sociology* 115:755-804.

MacKenzie, Donald, Fabian Muniesa, and Lucia Siu. eds. 2008. *Do Economists Make Markets? On the Performativity of Economics*. Princeton, N.J.: Princeton University Press.

Mas-Colell, Andreu, Michael D. Whinston, and Jerry R. Green. 1995. *Microeconomic Theory*. New York, N.Y.: Oxford University Press.

McMillan, J. 2002. *Reinventing the Bazaar: A Natural History of Markets*. New York: Norton.

Muniesa, Fabien. 2012. “A Flank Movement in the Understanding of Valuation.” Pp.24-38 in *Measure and Value* , edited by L. Adkins and C. Lury, Oxford: Wiley-Blackwell.

Ortega J. M., and W. C. Rheinboldt. 1970. *Iterative Solution of Nonlinear Equations in Several Variables*. New York, N.Y.: Academic Press.

Orton, Douglas J., and Karl E. Weick. 1990. “Loosely Coupled Systems: A Reconceptualization.” *The Academy of Management Review* 15:203-23.

Overdevest, Christine. 2011. “Towards a More Pragmatic Sociology of Markets.” *Theory and Society* 40:533-52.

Peterson, Karin. 1997. “The Distribution and Dynamics of Uncertainty in Art Galleries: A Case Study of New Dealerships in the Parisian Art Market, 1985-1990.” *Poetics* 25:241-63.

Podolny, Joel M. 1993. “A Status-Based Model of Market Competition.” *The American Journal of Sociology* 98:829-72.

——. 1994. “Market Uncertainty and the Social Character of Economic Exchange.” *Administrative Science Quarterly* 39:458-83.

——. 2001. “Networks as the Pipes and Prisms in the Market.” *The American Journal of*

Sociology 107:33-60.

Rasmusen, Eric. 2001. *Game and Information: An Introduction to Game Theory* (3rd Ed.). Malden, M.A.: Blackwell Publishers Inc.

Salganik, Mathew J., Peter Sheridan Dodds, and Duncan J. Watts. 2006. "Experimental Study of Inequality and Unpredictability in an Artificial Cultural Market." *Science* 311: 854-56.

Sauder, Michael, Freda Lynn, and Joel M. Podolny. 2012. "Status: Insights from Organizational Sociology." *Annual Review of Sociology* 38: 267-83.

Smith, Charles W. 1989. *Auctions: The Social Construction of Value*. New York. N.Y.: The Free Press.

Spence, A. Michael. 1974. Market Signaling: Informational Transfer in Hiring and Related Screening Processes. Cambridge: Harvard University Press.

Stark, David. 2009. *The Sense of Dissonance: Accounts of Worth in Economic Life.* Princeton, N.J.: Princeton University Press.

Tirole, Jean. 1988. The Theory of Industrial Organization. Cambridge, M.A.: The MIT Press.

Uzzi, Brian, and Ryon Lancaster. 2004. "Embeddedness and Price Formation in the Corporate Law Market." *American Sociological Review* 69:319-44.

Velthuis, Olav. 2003. "Symbolic Meanings of Prices: Constructing the Value of Contemporary Art in Amsterdam and New York Galleries." *Theory and Society* 32:181-215.

Weber, Max. [1922] 1978. *Economy and Society: An Outline of Interpretive Sociology*, Vol. 1, translated by Ephraim Fischoff *et al*., edited by Guenther Roth and Claus Wittich. Berkley: University of California Press.

Weick, Karl E. 1976. "Educational Organizations as Loosely Coupled Systems." *Administrative Science Quarterly* 21:1-19.

White, Harrison C. 1981a. “Production Markets as Induced Role Structures.” *Sociological Methodology* 12:1-57.

——. 1981b. “Where do Markets come from?” *The American Journal of Sociology* 87:517-47.

——. 2002. *Markets from networks: Socioeconomic Models of Production*. Princeton, N.J. : Princeton University Press.

——. 2008. *Identity and control: How Social Formations emerge*. 2d ed. Princeton, N.J. : Princeton University Press.

Whitford, Josh. 2002. “Pragmatism and the Untenable dualism of Means and Ends: Why Rational Choice Theory Does Not Deserve Paradigmatic Privilege.” Theory and Society 31:325-363.

Williamson, Oliver E. 1975. *Markets and Hierarchies, Analysis and Antitrust Implications: A Study in the Economics of Internal Organization*. New York, N.Y.: Free Press.

——. 1985. *The Economic Institutions of Capitalism: Firms, Markets and Relational Contracting*. New York: Free Press.

Yakubovich, Valery, Mark Granovetter, and Patrick McGuire. 2005. “Electric Charges: The Social Construction of Rate Systems.” *Theory and Society* 34:579-612.

Yogev, Tamar. 2010. “The social construction of quality: status dynamics in the market for contemporary art.” *Socio-Economic Review* 8:511–536.

Zelizer, Vivian. 1978. “Human Values and the Market: The Case of Life Insurance and Death in 19th Century American.” *The American Journal of Sociology* 84:591-610.

——. 1994. *Pricing the Priceless Child: The Changing Social Value of Children*. Princeton, N.J. : Princeton University Press.

——. 2004. “Circuits of Commerce.” Pp. 122-44 in *Self, Social Structure, and Beliefs:*

Explorations in Sociology, edited by Jeffrey C. Alexander, Gary T. Marx, and Christine Williams. Berkeley, C.A.: University of California Press.

Zhao, Wei. 2008. "Social Categories, Classification Systems, and Determinants of Wine Price in the California and French Wine Industries." *Sociological Perspectives* 51:163-199.

Zuckerman, Ezra W. 1999. "The categorical imperative: Securities analysts and the illegitimacy discount." *The American Journal of Sociology* 104:1398-1438.

——. 2004. "Structural Incoherence and Stock Market Activities." American Sociological Review 69: 405-32.

Appendices

Appendix A:

The following derives the equilibrium market profile $R(y)$, formed when value-informed pricing, rather than the W(y) mechanism, is at work.

The firm's cost function is

$$C(y;n) = qy^c / n^d . \tag{A1}$$

The consumers' valuation function is

$$V(y;n) = \frac{ry^a n^b}{\theta} . \tag{A2}$$

Since the firm can somehow estimate the valuation function of consumers, (A2) is supposed to be known to the firm, and thus is also the firm's revenue function:

$$R(y) = V(y; n) \tag{A3}$$

The necessary condition for the net cash flow of a firm, $R(y)$ - $C(y; n)$, to achieve maximum is

$$\frac{\partial V(y;n)}{\partial y} - \frac{\partial C(y;n)}{\partial y} = 0 . \tag{A4}$$

Substituting (A2) and (A1) into (A4) gives

$$\frac{1}{\theta} ray^{a-1} n^b = qc \frac{y^{c-1}}{n^d} . \tag{A5}$$

Solving for y yields the optimal production value $y^*(n)$. However, here we solve for n first,

$$n = \left(\frac{\theta qc}{ra} \right)^{1/(b+d)} y^{(c-a)/(b+d)} . \tag{A6}$$

Substituting (A6) into (A2) to eliminate n and renaming the resulting expression as $R(y)$, one has

$$R(y) = \left(\frac{qc}{a}\right)^{b/(b+d)} \left(\frac{r}{\theta}\right)^{d/(b+d)} y^{(ad+cb)/(b+d)}. \tag{A7}$$

Define B as

$$B \equiv \left(qc\frac{1}{a}\right)^{b/(b+d)} \left(\frac{r}{\theta}\right)^{d/(b+d)}. \tag{A8}$$

Thus (A7) can be rewritten as

$$R(y) = B\left[y^{(ad+cb)/b}\right]^{b/(b+d)}. \tag{A9}$$

Comparing (A9) and (A8) with the expression for White's W(y) curve (White 1981b, p.525, eq. 5, and p.529, eq. 11), it can be seen that $R(y)$ and $W(y)$ have rather similar expressions, except that the constant B is slightly different from the coefficient A in $W(y)$, and that there is no constant k in (A9).

Now I derive the (static) viability condition for the curve $R(y)$. Two conditions must be satisfied for the curve $R(y)$ to be viable. First, every firm's net income must be positive. Second, the net income achieves its (local) maximum. The mathematical expressions for the two conditions are

$$V(y;n) - C(y;n) > 0 \text{ , and} \tag{A10}$$

$$\frac{\partial^2 V(y;n)}{\partial y^2} - \frac{\partial^2 C(y;n)}{\partial y^2} < 0 . \tag{A11}$$

Substituting (A1) and (A2) into (A10) and (A11) yields

$$\frac{\theta q}{r} < y^{a-c} n^{b+d}, \text{ and} \tag{A12}$$

$$a(a-1)y^{a-c}n^{b+d} < \left(\frac{\theta q}{r}\right)c(c-1). \tag{A13}$$

Then, this leads to the condition for the $R(y)$ curve to be viable:

$$c>a. \qquad \text{(A14)}$$

Appendix B

In this appendix, the conditions for the presence (and absence) of vulnerability to disturbance in the price flocking model are discussed.

First, under the conditions of no quality ambiguity and no disturbances (i.e., σ, ε_{it}'s, and δ_{it}'s are all zero), the dynamic W(y) model specified in this paper can be reformulated as a deterministic iterative mapping. To see this, look at the process from run t to run t+1. In run t, each firm i makes an optimal output decision y_{it}^* maximizing its profit, and the optimal output decisions made by all the I firms in the market can be denoted by a vector $\boldsymbol{Y_t} = [y_{1t}^*, y_{2t}^*, \ldots, y_{It}^*]^T$. These volumes of outputs are sold in the market with the respective sales revenues $\boldsymbol{R'_t} = [R'_{1t}, R'_{2t}, \ldots, R'_{It}]^T$; each R'_{it} is determined by eq. 10 with $N_i = n_i$. In run t+1, each firm i uses the data $[\boldsymbol{Y_t}, \boldsymbol{R'_t}]$ to fit a $R_{t+1}(y)$ curve in the functional form specified in eq. 15 (or 16), and treats it as its revenue curve in run t+1. Then each firm finds its new optimal volume of output $y_{i(t+1)}^*$ by maximizing its profit $R_{t+1}(y) - C(y; n_i)$. All these output decisions together form the new vector $\boldsymbol{Y_{t+1}} = [y_{1(t+1)}^*, y_{2(t+1)}^*, \ldots, y_{I(t+1)}^*]^T$. Thus, the whole process can be formulated as a nonlinear iterative mapping $\boldsymbol{F}: \mathbb{R}^I \rightarrow \mathbb{R}^I$ (where $\mathbb{R}^I$ is the vector space with I dimensions), so that $\boldsymbol{Y_{t+1}} = \boldsymbol{F}(\boldsymbol{Y_t})$ (for t = 0, 1, …), where $\boldsymbol{F}$ is completely determined by the market parameters and simulation parameters (e.g., those in tables 1 and 2).

The existence of the equilibrium W(y) curve is equivalent to the existence of some point $\boldsymbol{Y}^* = [y_1^*, y_2^*, \ldots, y_I^*]^T$ in the $\mathbb{R}^I$ space, satisfying $\boldsymbol{Y}^* = \boldsymbol{F}(\boldsymbol{Y}^*)$. The point $\boldsymbol{Y}^*$ is called a *fixed point* with respect to mapping $\boldsymbol{F}$. The existence of the fixed-point $\boldsymbol{Y}^*$ can be easily judged by, and obtained from, the static W(y) model. Then, the issue of the vulnerability of the equilibrium to disturbances can be transformed to the issue of the stability of the fixed point $\boldsymbol{Y}^*$: that is, to see, for any random initial small disturbances $\Delta\boldsymbol{Y}$ to $\boldsymbol{Y}^*$, if the mapping $\boldsymbol{F}$ can lead the sequence $\{\boldsymbol{Y_t}\}^{t=0,1,\cdots}$, with $\boldsymbol{Y_0} = \boldsymbol{Y}^*+\Delta\boldsymbol{Y}$ and $\boldsymbol{Y_{t+1}} = \boldsymbol{F}(\boldsymbol{Y_t})$, return to the fixed point $\boldsymbol{Y}^*$. If it can, $\boldsymbol{Y}^*$ is called an *attracting* or *stable* fixed point with respect to $\boldsymbol{F}$, i.e., there exists a neighborhood $S(\boldsymbol{Y}^*, \delta)$ of $\boldsymbol{Y}^*$ (some open sphere centering on $\boldsymbol{Y}^*$ with radius δ), such that, for any $\boldsymbol{Y_0} \in S(\boldsymbol{Y}^*, \delta)$, the sequence $\{\boldsymbol{Y_t}\}^{t=0,1,\cdots}$ generated by $\boldsymbol{F}$ converges to $\boldsymbol{Y}^*$ as $t \rightarrow \infty$. If $\boldsymbol{Y}^*$ is an attracting fixed point, the corresponding equilibrium is locally stable and robust to disturbances. The theorem below gives a sufficient condition for judging if a specific equilibrium of the mechanism is locally stable.

Theorem B1: $(\boldsymbol{F'}|_{\boldsymbol{Y}^*})$ is the *Jacobian matrix* of $\boldsymbol{F}$ evaluated at $\boldsymbol{Y}^*$. The elements of the $I\times I$ Jacobian matrix are all the first-order partial derivatives of $\boldsymbol{F}$ evaluated at $\boldsymbol{Y}^*$. $\rho(\cdot)$ stands for the *spectral radius* of a matrix—the maximum among the absolute values of all eigenvalues of the matrix.

For any nonlinear mapping $\boldsymbol{F}$: $\mathbb{R}^I \rightarrow \mathbb{R}^I$, if there exists a fixed point $\boldsymbol{Y}^*$ with respect to $\boldsymbol{F}$, and $\boldsymbol{F}$ is differentiable at $\boldsymbol{Y}^*$, then,

if $\rho(\boldsymbol{F'}|_{\boldsymbol{Y}^*}) < 1$, the fixed point $\boldsymbol{Y}^*$ is (locally) stable, and thus robust to disturbances;

if $\rho(\boldsymbol{F'}|_{\boldsymbol{Y}^*}) > 1$, $\boldsymbol{Y}^*$ is unstable, and thus vulnerable to disturbances;

if $\rho(\boldsymbol{F'}|_{\boldsymbol{Y}^*}) = 1$, $\boldsymbol{Y}^*$ can be either stable or unstable, so further conditions are needed.

A proof of this theorem can be found in Ortega and Rheinboldt (1970, p.299-307). This theorem is widely used in searching for numerical solutions of nonlinear equations using iterative methods, and also in analyzing the stability of control systems. To get some flavor of the rationale for it, one can verify its correctness in the one-dimensional case. In such a case, $\boldsymbol{F}$ is reduced to some real-valued nonlinear function $f(y)$ with a single argument y; the existence of the fixed point is equivalent to the existence of some real number y^* satisfying $y^* = f(y^*)$; the Jacobian matrix reduces to $f'(y^*)$, the first-order derivative of f evaluated at y^*; the spectral radius reduces to the absolute value of $f'(y^*)$.

Note that although the theorem is incapable of judging the stability of the fixed point when $\rho(\boldsymbol{F'}|_{\boldsymbol{Y^*}}) = 1$, this would not be a serious issue in practice. The reason is, in empirical markets, the case in which the value of $\rho(\boldsymbol{F'}|_{\boldsymbol{Y^*}})$ is exactly equal to 1 is extremely rare, if not impossible.

To apply this theorem to the three simulation settings used in this paper, their respective Jacobian matrices evaluated at equilibrium and the corresponding spectral radiuses are calculated, using the "symbolic math toolbox" provided by the mathematical software MatLab (the codes are available upon request). The derivation and calculation are extremely tedious and complicated, though not difficult in principle, so it is almost impossible to do it without computer assistance. The spectral radius for setting 1 is $0.5 < 1$, thus setting 1 is stable; the spectral radiuses for settings 2 and 3 are equal to 2 and 1.33, respectively, both greater than 1 and thus unstable. These results are consistent with those given by the simulations.

In the case when the absolute quality ambiguity σ is no longer zero, the valuation curves of consumers becomes fuzzy bands. This changes the nature of the original mapping $\boldsymbol{F}$, which makes the equilibrium locally semi-stable.